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LEAF SCORCH ON FRUIT TREES.

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PART IV.—THE CONTROL OF LEAF SCORCH IN THE FIELD.

In considering methods of controlling cases of leaf scorch in the field, it is necessary to take cognisance of the various factors which may be operating in each case before taking measures to combat the trouble since it has been shown that several factors may be concerned.

It will be appropriate, therefore, at this point, to record the various points which have been found to be of significance to the problem and it will be necessary to bear in mind certain of these in considering the results of the experiments which are presented below.

In the first place, it is necessary to recognise that different fruits show considerable variation with regard to susceptibility to leaf scorch. Apples, gooseberries, currants, raspberries and strawberries are generally relatively susceptible, gooseberries in our experience being the most susceptible of all. Pears, plums, cherries and damsons are not usually affected, though cherries, plums and occasionally pears have been noted to scorch. Under scorching conditions, the foliage of cherries, plums and damsons usually becomes semi-chloratic, especially near the margins of the leaves and between the veins. In plantation 36, in which the apple Grenadier and the plum Victoria are planted alternately, practically every Grenadier has scorched badly whereas the plum trees have carried excellent foliage.

Varieties of the various fruits also exhibit significant differences in susceptibility. Among commercial apple varieties, Worcester Pearmain is perhaps one of the most resistant whilst Bramley's Seedling is also relatively resistant. The varieties Grenadier, Lord Grosvenor, Beauty of Bath, Jas. Grieve, Cox's Orange Pippin and Lane's Prince Albert appear to be highly susceptible.

Great differences have been noted between certain varieties of plums on scorching areas, Victoria being relatively resistant and Purple Pershore easily affected by the unfavourable soil conditions.

Of the various black currant varieties, Seabrook's Black seems to be much less susceptible than Baldwin or the varieties of the Victoria group.

No data have been collected with regard to red currant or raspberry varieties, though most varieties of the former appear to be highly susceptible.

Among the gooseberry varieties, whilst all are probably highly susceptible, perhaps Whinham's Industry is rather less susceptible than many other varieties.

Hatton and Grubb (*loc. cit.*) have shown that rootstocks may play an important part in cases of leaf scorch of apples and have emphasised the great liability to scorching of varieties worked on Malling Type V. They also found that trees on Malling Type II and Malling Type VII were also fairly susceptible.

Since, from the soil investigations, it appears possible to foretell fairly accurately whether the soil conditions occurring on any site are likely to be conducive to leaf scorch, it would appear worth while considering varieties and stocks in relation to resistance to scorching where soils favourable to scorch development are to be planted with fruit.

As previously mentioned, Hatton and Grubb also found a correlation between scorch and cropping, scorching tending to increase with increase in cropping. Our experience on this point is in agreement with this and, indeed, it has been frequently observed that scorch has been confined to the fruiting branches of trees.

The significance of certain soil conditions in cases of leaf scorch has already been discussed at length in Part III and it is unnecessary to elaborate soil factors further at this point.

It has already been indicated that certain points of management are of importance. Examples have been given which show that scorch tends to be suppressed when trees are grown " under grass " as opposed to arable conditions.

Finally, results obtained in pot experiments suggest that nitrogenous manuring will tend to promote the development of leaf scorch whilst potash manuring will tend to keep it in check. In support of this former suggestion, Tukey (14) working in U.S.A., found that when newly planted one year old and two year old apple trees were dressed with nitrate of soda at the rate of 8 lbs. per tree, the trees died during the course of the following season whereas in cases where dressings at the rates of 1 lb. and 2 lbs. per tree were given the trees developed " tip burn "—i.e. leaf scorch—in mid-season and became defoliated and later developed a second set of healthy foliage. The control trees which received no manure carried normal unscorched foliage throughout the season.

The work of Weiszmann (19) with barley in water cultures is also significant in relation to the action of nitrogenous manures on plants in the absence of potassium.

Two instances are on record in this country in which leaf scorch has been associated with potash deficiency in manurial experiments.

The first is mentioned by Hooper (4) as having occurred in an experiment in the Wye College Gardens and the second, at the Lancashire County Council Horticultural Station, Hutton, has been described by Sowman (11).

In this latter experiment, two varieties of apples—Bismarck and Grenadier—have received differential manurial treatments since 1912. On one plot, dung at

20 tons per acre per annum has been applied; on another, a complete fertiliser containing nitrogen, phosphates and potash has been given annually and in one case the trees have received a dressing of nitrate of soda at $1\frac{1}{2}$ cwts. per acre each spring. On this last plot, the trees have remained in a semi-stunted condition throughout the experiment and each season have developed severe leaf scorch.

Since the spring of 1923, one of these scorched trees has received a dressing of sulphate of potash at the rate of 2 cwts. per acre each year in addition to the usual dressing of nitrate of soda and after three years of this treatment—during 1925—the amount of leaf scorch on the tree was negligible and shoot growth considerably increased. The trees which have not received the sulphate of potash in addition to the nitrate of soda have continued to exhibit severe leaf scorch each season. It should be noted that the soil at this centre is fairly heavy and the "available" potash at the time of planting is stated to have been 0.018 per cent.

During the course of the past five seasons, the writer has carried out field investigations with a view to determining how far manurial treatment and "grassing down" will prove of practical value as measures for controlling leaf scorch. An account of these is given in the following two sections.

Manurial Experiments.

In the manurial experiments, the aim has been generally to test the action of potash manures in cases of leaf scorch and in one or two cases the effects of other manures—especially dung—have been examined.

In certain of the experiments, records on leaf scorch have been kept for each tree on the experimental area over a number of seasons—Class A. Experiments—and, in others, the effects of the various treatments have been judged by less detailed inspections of the trees—Class B. Experiments. In the first class of experiment, records of cropping have also been taken for each tree.

The method used in marking the degree of scorch was adopted by Mr. R. C. Gaut, M.Sc., Agricultural Organiser for Worcestershire, and the writer as a practicable one after trial on a typical scorch area. The classes used are as follows :—

Nil.—Tree entirely free from scorch.

Very Slight (V.S.).—Tree shows scorch on a few leaves or scorch is confined to one branch.

Slight (S.).—A fair scattering of scorched leaves occurs over the tree but the foliage is generally good and not seriously crippled.

Slight to Medium (S.M.).—Doubtful cases between slight and medium.

Medium (M.).—Scorching is present on most of the leaves but the foliage is still fairly good and shoot growth is proceeding.

Medium to Bad (M.B.).—Doubtful cases between medium and bad.

Bad (B.).—Scorch occurs on practically every leaf and the foliage is in a crippled condition. Defoliation may occur. Shoot growth is practically nil.

Very Bad (V.B.).—Only used in exceptional cases in which the tree is almost dead from leaf scorch.

For purposes of presenting these results in a concise manner, numbers have been substituted for the above classes as follows :—

0 = Nil.	½ = V.S.	1 = S.	1½ = S.M.
2 = M.	2½ = M.B.	3 = B.	4 = V.B.

It is realised, of course, that a method based on eye judgment is open to criticism but we would point out that in these experiments we have often started with trees which for twelve or twenty years have been total failures due to leaf scorch and it has been our object to see whether by several seasons of definite treatment such trees could be converted into useful ones.

Certain of the experiments below are marked with an asterisk. In such cases the experiments have been carried out jointly with Mr. R. C. Gaut. The data have been analysed by the writer but Mr. Gaut accepts joint responsibility for the presentation of the results of these and for the opinions expressed and the conclusions drawn relative to the results.

Class A. Experiments.

†*Experiment* 1.—*Areas* 37, 37a.

These areas occur on an experimental plot at Long Ashton Research Station on which a manurial experiment with gooseberry bushes, variety, Keepsake, has been in progress since spring, 1921. There are sixteen manurial plots in the experiment, there being eight different treatments, so that each treatment is given in duplicate. The plots are laid out side by side in strip fashion, each containing forty bushes in two rows. There is a single buffer row of bushes between each two plots.

The scheme of manurial treatments is shown in Table X.

Complete "organic" manure consists of dried blood, steamed bone flour, sulphate or muriate of potash.

Complete "inorganic" manure consists of sulphate of ammonia or nitrate of soda, superphosphate, sulphate or muriate of potash.

Nitrogen is applied at 50 lbs. per acre ; phosphates at 120 lbs. "total phosphates" per acre ; potash salts at 100 lbs. K_2O. per acre.

The plots are numbered in order across the area. The soil varies across the plots from 1 to 16 in a direction practically at right angles to the length of the

† A complete account of this experiment is given in *Journal of Pomology and Horticultural Science*, Vol. VI, No. 3, 1927.

TABLE X.

Plot Nos.	Manurial Treatments.
1, 9 ..	No manure.
2, 10 ..	Dung at 10 tons per acre each spring.
3, 11 ..	Complete "organic" manure (non-bulky) each spring—to supply nitrogen, phosphates, potash.
4, 12 ..	Complete "inorganic" manure, each spring—to supply nitrogen, phosphates, potash.
5, 13 ..	Complete manure. Mixture of "organic" and "inorganic" materials in equal parts, each spring.
6, 14 ..	As 5, 13, less nitrogen, each spring.
7, 15 ..	As 5, 13, less phosphates, each spring.
8, 16 ..	As 5, 13, less potash, each spring.

plots, the data for area 37 being representative of the soil in Plot 1, and those for area 37a of the soil on Plot 16.

During the first season after planting, it was noted that with the exception of a few bushes on Plots 1 to 4, all bushes exhibited leaf scorch and that scorching was especially marked on the bushes on Plots 9 to 16.

Since 1921 the distribution of scorch on the plots has been recorded each season and it has been evident that this has been greatly affected by certain of the manurial treatments. The records obtained in 1924, 1925 and 1926 are shown in Table XI.

TABLE XI.

Series.	Plot Nos.	27/6/24.	23/6/25.	26/8/25.		21/6/26.
		Nos. of affected bushes.	Nos. of affected bushes.	Total Nos. affected bushes.	Nos. severely affected.	Nos. of affected bushes.
A.	1	0	0	36	10	0
	2	3	1	17	2	0
	3	4	1	16	0	0
	4	1	1	12	0	0
	5	3	0	8	0	0
	6	0	2	15	0	0
	7	2	4	19	1	0
	8	28	28	38	32	31
B.	9	26	24	34	30	25
	10	10	6	23	11	2
	11	7	7	22	9	1
	12	11	5	15	3	2
	13	4	5	18	5	4
	14	8	4	19	5	2
	15	3	5	24	0	1
	16	35	27	35†	26	26

† Also total number bushes on plot.

Two points stand out clearly in the results. The more striking of these is that leaf scorch during the three seasons has been most severe on Plots 8, 9, 16 and the other is that it has been more prevalent on the plots in Series B. than on those in Series A. During the period, scorch has only been widespread on Plot 1—an unmanured plot—on one occasion and at that time the trouble was more prevalent than usual on all plots. When it is remembered that the soil conditions on the Plot 1 side of the area are apparently not very conducive to leaf scorch, it soon becomes evident on examining Table XI. in conjunction with Table X. that dung and potash have exercised marked controlling effects over scorching on the experimental area. If we consider the results in Series B., where the whole area may be regarded as a "scorch" area, it is seen that the only two plots on which appreciable scorch occurs are Plot 9, receiving no manure, and Plot 16, receiving nitrogen and phosphates but not potash. Where dung or complete artificials are applied, control is exercised and this is not decreased by the omission of either nitrogen or phosphates.

It should be added that, from the data on growth and cropping which have been obtained in this experiment, it appears that manuring with nitrogen and phosphates in the absence of potash has actually proved detrimental.

Experiment 2.—Area 10.

This area is planted with apple trees and a few young plum trees. The majority of the apple trees were nineteen years old when the experiment was commenced in the spring of 1924. The original varieties were Stirling Castle, Warner's King and Newton Wonder and were worked on seedling stocks. They had all failed to make useful trees, many had "died back" and several had been regrafted with Worcester in the hope of obtaining success with this variety. All efforts of the grower to stimulate growth had been unsuccessful and the trees had remained crippled with scorch, loose in the ground, moribund and unfruitful.

For the purposes of the experiment, the worst area in the plantation was selected. Thirty-six trees were growing on it, thirty-two of which were apple trees and four newly planted plums. One of the apple trees was subsequently removed. No portion of the area was left untreated as a control as the area was small and it was felt that if a large effect could be produced on trees which had failed for nineteen years with the addition of only one factor the result could be unquestionably attributed to the factor introduced.

The only experimental treatment given has been an annual spring dressing of sulphate of potash. No other manure has been given during the period of the experiment and cultivation has been maintained at a high standard throughout the period.

The dressings of manure have been applied as follows :—

Spring, 1924 :	Sulphate of potash at	3 cwts.	per acre.
Spring, 1925 :	do.	4	do.
Spring, 1926 :	do.	4	do.

Records were taken on each tree during the late summer of each of the above seasons and these are summarised below in Table XII.

TABLE XII.

Leaf Scorch Records, Area 10.

Date of Recording.	Total points awarded for scorch.	Points as Percentages of 1924 Record.	Total points awarded for scorch on untreated Area.
28/8/24	42.5	100.0	Not recorded.
30/7/25	11.0	25.8	do.
10/8/26	5.5	12.9	26

It will be seen from the table that the amount of leaf scorch has been markedly reduced on the trees. Two points call for mention in connection with the results. The first is that on the occasion of the taking of the first records a visible improvement in the condition of the trees was already noticeable and the second that, in addition to the improvement recorded in leaf scorch, a paying crop was harvested from the area in 1925—the first obtained for many years.

The pale colour of the foliage originally present on the plum trees on the area has given place to a healthy green colour since the treatment has been given.

In 1926 scorch records were taken on eighteen trees located on an area immediately adjoining the experimental plot. These trees had always been regarded as suffering less from leaf scorch than those on the experimental plot. It will be seen in the table that on this occasion the total points awarded was 26, an average of 1.4 per tree as against 0.17 per tree on the treated plot.

The results obtained at this centre show beyond doubt that the leaf scorch occurring there can be controlled by adequate potash manuring.

**Experiment* 3.—*Area* 22.

This area is planted out partly with bush apples of the varieties Grenadier, Grosvenor, Early Victoria and Worcester Pearmain, probably on Malling Type I stock, and partly with plums, chiefly Pershore Egg. The apple trees are somewhat over twelve years of age and they have been known to scorch more or less severely for several years. In 1922, the condition of the trees became serious and the grower in consequence dressed the whole area with " Sulpho potash " (containing 20 per cent. K_2O) at a rate of 10 cwts. per acre. In 1923, the trees showed much improvement and it was decided to continue potash dressings to a

part of the area and to record the distribution of scorch on the apple trees for a few seasons. The experiment was subsequently continued until 1925 and records were taken in 1923, 1924 and 1925. It was not possible to record the trees in 1926 owing to a serious aphis attack.

The manurial dressings applied to the area since 1922 are as under :—

Spring, 1923 : "Sulpho potash" at 10 cwts. per acre to whole of area.

Spring, 1924 : Sulphate of potash at 3 cwts. per acre to rows 3, 4 and 5.

Spring, 1925 : Sulphate of potash at 3 cwts. per acre to rows 3, 4 and 5.

Row 6 received the manurial dressing on one side in 1924 and 1925 and row 7 received no manure during these two years.

Cultivation conditions during 1922, 1923 and 1924, were good ; during 1925 grass strips were left in the tree rows and the alley ways were only given winter ploughing treatment so that during that summer the plot was very weedy and the foliage on many of the trees in consequence showed signs of low nitrogen conditions.

The varieties occur in the rows as follows :—

Row 3 : 3 Lord Grosvenor, 1 Grenadier, 1 Early Victoria, 15 Worcester Pearmain.

Row 4 : 5 Early Victoria, 15 Worcester.

Row 5 : 20 Early Victoria.

Row 6 : 20 Early Victoria.

Row 7 : 1 Early Victoria, 19 Grenadier.

Since nineteen of the trees in Row 7 are of the variety Grenadier, they are not suitable for comparison with those in the other rows but they are useful to show the effect of grass in 1925.

In 1924, the Early Victoria, Grosvenor and Grenadier trees carried good crops and the Worcester trees medium crops and in 1925 all varieties excepting Worcester again bore crops but of poor quality.

The records obtained are summarised in Table XIII.

TABLE XIII.

Leaf Scorch Records, Area 22.

Row No.	Manurial treatment in addition to "Sulpho potash," 1923.	Total points awarded.		
		8/8/23.	12/8/24.	5/8/25.
3	Potash each spring	17	5	0
4	do.	14.5	3.5	0
5	do.	15	4.5	0
6	½ Potash each spring.	Not recorded.	7.5	0.5
7	Nil	do.	18.5	4.5

These results again indicate that a substantial reduction in leaf scorch was effected by the manurial treatment on the treated area up to the summer of 1924. The further reduction observed in 1925 might have been partly due to grass effect as a marked reduction also occurred on the untreated plot during the last season when the foliage suggested "low nitrogen" conditions.

Experiment 4.—*Area adjoining* 18c.

The soil conditions at this centre are similar to those on area 18c. the surface and subsoil being almost identical in texture to that at 18c. whilst the subsoil overlies a bed of soft sandstone rock. The area is planted out with seventy-two bush apple trees—Newton Wonder on Malling Type I stock—and at the time of commencing the experiment the trees were thirteen years old. Except in a few cases, they had made poor growth since planting and had exhibited leaf scorch from an early age. When the experiment was commenced the trees had mostly reached the small leaf stage. It was originally intended to treat this block and two other similar blocks occurring in adjoining plantations with annual dressings of sulphate of potash at the rate of 2 cwts. per acre for a number of seasons and to record the results.

During the first season after the initial manurial dressing had been applied, it was found impossible to continue cultivation over the area and the soil became overgrown with a rank growth of grass. As a result of this, the trees suffered severely and the majority of them exhibited marked yellowing of foliage whilst leaf scorch did not occur on any tree and much of the foliage was shed by the end of July. As it was doubtful whether the plot would be cultivated in the following season, the scheme of manurial treatment was modified. Under this scheme dressings of nitrate of soda at 4 cwts. per acre and of sulphate of potash at 3 cwts. per acre were applied in early March. The grass was to be kept short by cutting during the growing season. No cultivation was given until about mid-summer but previous to this the trees, as the result of the nitrogenous manure, made excellent shoot growth and carried a healthy set of well developed green foliage. By the end of the season, some of them had made shoots 3 feet in length and many which had been hitherto stunted made leader growth varying from 1 foot to 2 feet.

The foliage throughout the season suggested high nitrogen conditions but yet there was not a single case of leaf scorch recorded on the area. The result suggests that the leaf scorch previously present on the plot can be controlled by potash dressings.

This experiment together with the two others at this centre are to be continued for two or three seasons further during which the use of nitrogenous and potassic manures will be further investigated.

******Experiment* 5.—*Area* 27.

The area concerned in the experiment at this centre is approximately 2⅔ acres in extent. It was first inspected during the summer of 1920 when the apple trees and gooseberry bushes growing on it were observed to be in extremely poor condition, the trees showing severe leaf scorch whilst the gooseberry bushes were practically defoliated following a severe attack of scorching.

Further observations were made on the area in August, 1922, when conditions were noted to be similar to those observed in 1920. On this occasion, attention was given to drainage conditions and it was noted that these were unsatisfactory especially over the area on which the experimental plots 3 and 4 were later laid down. A drain was run through this particular area during the course of the following winter.

The gooseberry bushes were removed during the winter of 1923-24 as they were in a deplorable condition.

At this centre no untreated plot was left as a control owing to the fact that a considerable amount of money had already been lost on the plantation and it was essential to effect improvement over the area without delay. Four plots were accordingly marked out to cover the whole of the area over which scorch appeared to be most severe.

The details regarding numbers of trees and varieties on each plot, together with the experimental treatments and data relating to leaf scorch and cropping, are contained in the Tables below—Tables XIV.–XVIII.

TABLE XIV.

Manurial Treatments.

Dates of application. Winters.	Treatments.				
	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.
1923-24 ..	16 tons Dung per acre.	Superphosphate at 10 cwts. per acre. Sulphate of Potash at 3 cwts. per acre.	Superphosphate at 10 cwts. per acre.	Sulphate of Potash at 3 cwts. per acre.	No Manure.
1924-25 ..	do.	Sulphate of Potash at 3 cwts. per acre.	Sulphate of Potash at 3 cwts. per acre.	do.	do.
1925-26 ..	Sulphate of Potash at 3 cwts. per acre.	do.	do.	do.	do.

TABLE XV.

Showing Total Leaf Scorch Points—Period 1924–26 *and Infection Values* 1924.

Plot No.	Stirling Castle.					Worcester Pearmain.					Jas. Grieve.				
	No. of trees on plot.	Total Leaf Scorch Points.			Infection value.*	No. of trees on plot.	Total Leaf Scorch Points.			Infection value.	No. of trees on plot.	Total Leaf Scorch Points.			Infection value.
		19/8/24	5/8/25	29/7/26			19/8/24	5/8/25	29/7/26			19/8/24	5/8/25	29/7/26	
1	52	24.5	6.5	8.5	0.47	52	43.5	3	2	0.84	39	71	28.5	30	1.82
2	36	25	17.5	22	0.70	24	33.5	10	1	1.40	24	39.5	18.5	34.5	1.65
3	12	8	6.5	9	0.67	23	30	9.5	8.5	1.30	12	22	10	13.5	1.83
4	33	19.5	8.5	10.5	0.59	22	14	5.5	4.5	0.64	32	59.5	15	30.5	1.86
5	30	—	3	10		20	—	5.5	9.5		30	—	21	44	

* Infection Value $= \dfrac{\text{Total Points}}{\text{No. of trees on plot.}}$

TABLE XVI.

Showing Percentage Decrease in Leaf Scorch on Treated Plots—Period 1924–26.

Plot No.	Stirling Castle.				Worcester Pearmain.				Jas. Grieve.			
	Season 1924.	% 1924 scorch present.		Net % decrease over period.	Season 1924.	% 1924 scorch present.		Net % decrease over period.	Season 1924.	% 1924 scorch present.		Net % decrease over period.
		1925.	1926.			1925.	1926.			1925.	1926.	
1	100	26.5	34.7	65.3	100	6.9	4.6	95.4	100	40.1	42.3	57.7
2	100	70.0	88	12.0	100	29.9	32.8	67.2	100	46.8	87.3	18.7
3	100	81.3	112.5	−12.5	100	31.7	28.3	71.7	100	45.9	61.4	38.6
4	100	43.6	53.8	46.2	100	39.3	32.1	67.9	100	25.2	51.3	48.7

TABLE XVII.

Showing Percentage Increase in Leaf Scorch in Period 1925–26 and Infection Values 1925.

Plot No.	Stirling Castle.				Worcester Pearmain.				Jas. Grieve.			
	Infection Values 1925.	% Season 1925.	% 1925 Leaf Scorch present 1926.	% Increase Leaf Scorch in 1926.	Infection Values 1925.	% Season 1925.	% 1925 Leaf Scorch present 1926.	% Increase Leaf Scorch 1926.	Infection Values 1925.	% Season 1925.	% 1925 Leaf Scorch present 1926.	% Increase Leaf Scorch in 1926.
1	0.11	100	130.8	30.8	0.06	100	66.7	−33.3	0.40	100	105.3	5.3
2	0.49	100	120.6	20.6	0.42	100	110	10	0.77	100	186.5	86.5
3	0.54	100	138.5	38.5	0.41	100	90	−10	0.83	100	135	35
4	0.26	100	123.5	23.5	0.25	100	81.8	− 8.2	0.47	100	203.3	103.3
5	0.10	100	333.3	233.3	0.28	100	172.7	72.7	0.70	100	209.5	109.5

TABLE XVIII.

Cropping Records.

Plot No.	Season.	Stirling Castle.					Worcester Pearmain.					Jas. Grieve.				
		Heavy.	Medium.	Light.	Nil.	Trees on Plot.	Heavy.	Medium.	Light.	Nil.	Trees on Plot.	Heavy.	Medium.	Light.	Nil.	Trees on Plot.
1	1925	38	11	3	0	52	37	14	1	0	52	36	2	0	1	39
	1926	23	7	6	16		19	8	9	16		13	14	9	3	
2	1925	22	13	1	0	36	14	9	1	0	24	22	2	0	0	24
	1926	7	6	13	10		12	8	4	0		3	8	10	3	
3	1925	12	0	0	0	12	11	12	0	0	23	10	2	0	0	12
	1926	1	2	1	8		0	10	9	4		4	0	5	3	
4	1925	13	13	5	2	33	10	11	1	0	22	19	13	0	0	32
	1926	24	4	5	0		14	7	1	0		22	10	0	0	
5	1925	2	9	14	5	30	4	16	0	0	20	10	20	0	0	30
	1926	26	2	2	0		17	3	0	0		22	8	0	0	

In these Tables it will be noted that during the course of the experiment some records were taken of trees which had received no manurial treatment. These trees are located on a plot which adjoins Plots 1 and 4 and were recorded from 1925 as it appeared on inspection in that year that this might usefully be done.

It should be mentioned that the Stirling Castle trees are stated to be on "crab" stocks and the Worcesters and Grieves on Paradise.

In the foregoing Tables, the data from the plots have been summarised and are treated in various ways in an attempt to show to what extent the manurial treatments have tended to control leaf scorch.

In Table XIV. the manurial treatments given over the period of the experiment are set out. The original plan was as shown for the winter of 1923-24, the superphosphate treatment being included as the "available" phosphate had been shown to be extremely low. The treatment was discontinued and potash treatment substituted in view of the condition of the trees on the plot and the desire of the owner to effect improvement. Potash treatment was substituted for dung in winter 1925-26 as no dung was available on that occasion.

In the analysis of the leaf scorch and cropping data, the records for the three varieties have been treated separately and the results are presented foı each variety in Tables XV. to XVIII.

In Table XV. the numbers of trees of each variety on the five plots are given and the total points for leaf scorch for the three seasons 1924 to 1926 are recorded in the cases of Plots 1 to 4 and for the two seasons 1925 and 1926 in the case of Plot 5. Columns showing "Infection Value" for the three varieties on Plots 1 to 4 in August, 1924, are included from which it is possible to compare the degree of leaf scorch present on the varieties on the various plots. In comparing these, it should be remembered that the trees had already received one dressing of the manures previous to the 1924 records being taken.

It will be observed from these values that the trees of the variety Jas. Grieve were most severely affected, those of the variety Worcester Pearmain being second in order of severity whilst those of the variety Stirling Castle were least affected. It will also be noted in this Table that the leaf scorch points awarded were generally much higher in 1924 than in the subsequent years.

In Table XVI. the leaf scorch points for the three seasons are calculated as percentages of the points awarded in 1924 and from these it is possible to trace the behaviour of the trees in relation to scorching over the three seasons and to compare the effects of the treatments on the plots. In the last column for each variety, the nett decrease in scorching for the period is given.

The following points are revealed by these data.

1. There is a substantial percentage decrease in leaf scorch with all varieties on all plots except in the case of Stirling Castle on Plot 3

where there is a 12 per cent. increase and on Plot 2 where the decrease is only 12 per cent.

2. The greatest improvement has occurred in the variety Worcester Pearmain, the results for the other two varieties being on the whole similar in amount and not so consistent as for Worcester.

3. The largest effects in all cases have been produced on Plot 1, which received dung for the first two years and sulphate of potash in the third year. The second largest reductions have occurred on Plot 4 which has received sulphate of potash only.

4. The results obtained on Plots 2, 3 and 4 with Worcester Pearmain are very similar and the decreases recorded for these are much smaller than for Plot 1.

It is necessary in considering these results to take into account the cropping data recorded in Table XVIII. Examination of these will show that the crops can be placed in the following broad categories.

Plot 1.	1925.	Stirling heavy ;	Worcester heavy ;	Grieve heavy.
	1926.	,, medium ;	,, medium ;	,, medium.
Plot 2.	1925.	,, heavy ;	,, heavy ;	,, heavy.
	1926.	,, light ;	,, medium ;	,, medium to light.
Plot 3.	1925.	,, heavy ;	heavy to medium. ;	,, heavy.
	1926.	,, light ;	,, medium ;	,, medium.
Plot 4.	1925.	,, heavy to medium ;	,, heavy to ,, medium ;	,, heavy.
	1926.	,, heavy ;	,, heavy ;	,, heavy.

It will be seen from the above grouping that there has not been much difference in the cropping of the varieties on the plots, although all varieties on Plot 4 appear to have borne rather heavier crops in 1926 than on the other plots. The differences in cropping would thus not appear to be responsible for the differences in effect brought out in Table XVI.

Table XVII. is included to bring out a point of interest with regard to the behaviour of the trees over the period of 1925-26.

During that period, in all cases with the exception of three, the varieties on the various plots showed increases in the amounts of leaf scorch. In the table the " infection values " for 1925 are given and the amounts of scorch present in 1926 are shown as percentages of those recorded in the previous year.

The salient points of the data are as follows :—

1. The percentage increase is smallest among the varieties in the case of Worcester Pearmain and largest in that of Jas. Grieve.

2. The smallest increases with reference to the treatments occurred on Plot 1.
3. The largest increases in the case of all varieties are recorded on Plot 5.

In connection with 3, it is essential to refer to the Table of cropping data for Plots 1-4 and to compare the records with those of Plot 5 below before drawing conclusions.

Plot 5.	1925.	Stirling light ;	Worcester medium ;	Grieve medium to heavy.
	1926.	„ heavy ;	„ heavy ;	„ heavy.

The cropping will thus be seen to be similar to that on Plot 4 in that all varieties cropped heavily in 1926 although the crops for 1925 were smaller than on Plot 4.

It would appear from these data that during 1926 some factor common to all plots was operating which was conducive to leaf scorch.

The trees which had received the dung treatment were able to resist the factor most efficiently whilst those on the unmanured plots were not able to withstand the unfavourable condition so well as the manured trees.

The variety Worcester Pearmain, which is a relatively resistant variety to leaf scorch, withstood the conditions on all plots excepting on the unmanured area.

Taken as a whole, the data obtained at this centre show that considerable improvement as regards leaf scorch has resulted from the use of dung aud potash manuring, especially from the former.

It should be noted that in addition to the improvements to the foliage, the trees have carried heavy crops of fruit of high class quality which has not previously occurred.

**Experiment 6.—Area 32.*

The experimental area at this centre comprises approximately one-third of an acre. It is planted with bush apple trees of the varieties Jas. Grieve and Lord Derby. The trees which are approximately seventeen years of age are all worked on " Paradise " stocks and it is probable that the stock generally used is Malling Type V. The growth over the plot is rather uneven. There are a few really stunted specimens but the majority have made fairly good growth though for the last few years those of the variety Derby have carried small poorly developed foliage suggesting lack of vigour. The variety Grieve has been affected most with leaf scorch during the period of the experiment.

The characters of the soil and subsoil at this centre have been described in Table VII where reference is made to the fact that the conditions over the area suggest unsatisfactory drainage due to subsoil features.

The details of the manurial treatments and of the leaf scorch data, etc., are presented in Tables XIX. and XX.

TABLE XIX.

Manurial Treatments. Area 32.

Plot Nos.	Spring Dressings.			
	1923.	1924.	1925.	1926.
1	Nil.	Nil.	Nil.	Nil.
2	Ground Limestone at 3 tons per acre.	Nil.	Nil.	Nil.
3	Ground Limestone at 3 tons per acre + Sulphate of Potash at 3 cwts. per acre.	K_2SO_4 at 3 cwts. per acre.	K_2SO_4 at 2 cwts. per acre.	K_2SO_4 at 3 cwts. per acre.
4	Sulphate of Potash at 3 cwts. per acre.	K_2SO_4 at 3 cwts. per acre.	K_2SO_4 at 2 cwts. per acre.	K_2SO_4 at 3 cwts. per acre.

TABLE XX.

Leaf Scorch Data. Area 32.

Plot Nos.	Nos. of Trees on Plots.	Leaf Scorch Markings.				
		23/8/22	9/8/23	11/8/24	6/8/25	30/7/26
1	46	12*	15.5	27.5	9	2.5
2	22	18	18	18.5	7.5	6.5
3	35	19	18	27	7	1.5
4	30	7	9	24.5	8	1.5

* The figures in this column show numbers of trees affected with leaf scorch on this occasion and do *not* refer to "markings."

In connection with the manurial treatments shown, it should be stated that the limestone treatments at this centre were included owing to a misunderstanding, these having been proposed for Experiment 7, where the soil showed a "lime requirement" of 0.30 per cent.

In addition to leaf scorch data, records of cropping were also taken. These are not set out in detail as the results show that they have not been important in relation to scorching on the area. It is sufficient to say that both varieties cropped heavily in 1925 and that in the other seasons Grieve has cropped fairly heavily and Derby rather lightly.

It has not been considered worth while to present a detailed analysis of the leaf scorch data for each variety, as it seems obvious from the Table that some factor other than those introduced by the manurial treatments has determined

the degree of scorching over the period. Thus in 1924 there is a sharp rise in the amount of scorch present on all plots and a progressive fall from that time until 1926 when the amounts of leaf scorch present on all the plots was for practical purposes negligible. No explanation can be offered at present regarding the observed behaviour of the trees. It has not been due to variation in management. It is, of course, possible that it may have been due to water conditions in the soil but no opportunity has been afforded of following these in detail.

**Experiment 7.—Area 31.*

The experimental trees at this centre consist of apple trees of the varieties Cox's Orange Pippin and Rival trained as espaliers between rows of standard plum trees of the variety Purple Pershore. The apple trees are probably all worked on Malling Type V rootstock.

The plot is very closely planted and in view of the very heavy cropping of the plums the time for the removal of the apple trees is possibly overdue.

These latter are probably seventeen years of age and during the last few years have scorched consistently, especially those of the variety Cox's Orange Pippin. There have been very few really bad cases, however, and the trees all continue to make good shoot growth and have borne some good crops of high grade fruits.

For the purpose of the experiment the area has been divided into two plots, sulphate of potash at a rate of 3 cwts. per acre has been applied to one plot each spring and the other has not been given any manurial treatment whatsoever. The dressings have been applied from 1923 to 1926 inclusive.

From the soil data on page 273, it will be seen that these suggest the land being in poor heart both as regards phosphates and potash while there is no carbonate of lime present in either soil or subsoil and these both show an appreciable "lime requirement."

As stated in the previous experiment, it was originally proposed to include a "lime" plot at the centre but owing to a misunderstanding this plot was established on Area 32.

Detailed records relating to leaf scorch and cropping were taken only in 1925 and 1926. Those relating to the former are shown in Table XXI.

TABLE XXI.

Leaf Scorch Records. Area 31.

Plot No.	Treatment.	No. of Trees on Plot.	Leaf Scorch Markings.	
			1925.	1926.
1	Sulphate of Potash	39	29	14.5
2	No Manure.	37	33	14

The data have not been analysed in detail for the varieties as these are present in approximately equal numbers on the plots and the results suggest that the differences observed in the occurrence of leaf scorch in the areas are due to some factor other than the experimental treatment. This centre will be studied further in the future.

CLASS B. EXPERIMENTS.

Experiment 1.—*Area* 26a.

The area is planted with gooseberry bushes, variety Whinham's Industry, and black currant bushes, variety Baldwin. They were four years old when first seen by the writer on August 3rd, 1924. At that time they were all badly scorched, the gooseberry bushes being stunted and partially defoliated whilst the currant bushes were carrying a crop of fruits which they were unable to ripen.

Shortly after the visit the area was dressed with muriate of potash at 3 cwts. per acre, in the case of each fruit an unmanured plot being left as a control. A further dressing of muriate of potash was given to the treated plots in the spring of the following year.

The results obtained at this centre were very striking. In 1925 the foliage on the untreated portions was badly scorched in June whilst on the treated plots it was perfectly healthy.

In the case of the gooseberry plot the untreated plot stood out as a brown patch against the green of the treated plot and was discernible in this way when viewed from a hill half a mile away.

The difference between the treated and untreated areas was maintained during the rest of the season and since then the whole area has been given annual potash dressings and scorch has been eliminated.

Experiment 2.—*Area* 34.

This area was visited for the first time in early October, 1922. It had been planted out six years previously with bush and standard trees, the former on a "Paradise" stock and the latter on " free " stocks. Over a portion of the area, the trees had been originally interplanted with black currants and gooseberries, whilst the remainder of the area was utilised for growing mangels, turnips and garden crops.

The apple trees had scorched badly since planting and the black currant and gooseberry bushes had been so severely affected that many had died out, and when seen in 1922, the initial survivors were all practically dead. The root crops all exhibited marginal leaf scorch.

The main apple varieties on the plot are Lane, Allington, Cox, Newton and Bramley, and of these Lane and Allington were most severely affected.

Previous to 1922 the trees had occasionally been manured with weak liquid manure. Up to 1921 the whole of the area—about 3 acres—had been cultivated but matters were so bad then that one half of the area was allowed to tumble down to grass and weeds, the remainder being kept under cultivation for root crops. Following the visit of the writer in 1922, it was decided to continue the half grass, half arable treatment and in addition to apply annual dressings of kainit at rates from 3 to 5 cwts. per acre over the whole area, and to run poultry intensively over the grassed portion. This treatment has been followed since that time and the results obtained have been very marked. Each season the trees have carried excellent crops and with the exception of a few extremely bad trees of Allington Pippin and Lane's Prince Albert the trees have been free from leaf scorch. Those on the grassed area have generally exhibited symptoms of nitrogen starvation and on such trees the grassing treatment has doubtless helped to control leaf scorch.

On the cultivated area, however, scorching has disappeared and the trees for the last three seasons have made excellent growth and carried foliage of excellent quality which shows beyond doubt that leaf scorch on the area can be controlled by potash manuring.

Previous to 1922 the plantation was a dismal failure, but since then the results have been so good that the owner has decided to plant out a further area of 20 acres of similar land in 1927.

Experiment 3.—*Area* 35.

This area of approximately 1 acre is planted with bush apples and the ground between the trees is utilised partly for growing vegetables and partly for raising seedling forest trees. The trees are said to be on a "Paradise" stock. The main varieties are Worcester, Allington, Jas. Grieve and Cox's Orange Pippin. They are mostly planted in the winter of 1919, the remainder being planted during the following winter. The trees failed to start properly, all exhibiting severe scorch, especially at one end of the plantation planted with Worcester and Cox's Orange Pippin, where the soil was noted to be unusually shallow and gravelly.

An experimental dressing of kainit at 8 cwts. per acre was applied to two portions of the plot in February, 1922, the plot being divided into thirds for this purpose. The untreated third was situated between the two treated thirds. Practically no result due to the treatment was observed during the first season, but in the second season the foliage on the untreated plot contrasted strongly with that on the manured plots, leaf scorch being almost entirely absent from the trees on these latter plots, whilst on the control trees scorching was as severe as in previous years. The experiment was not continued beyond this point as the results were so definite that the owner decided to apply potash manures as a routine in subsequent seasons.

Experiment 4.—*Area* 25.

This area was taken over for nursery purposes in 1921. It was then a portion of a pasture. The turf was dug in that year and the ground planted with various nursery stock—apple stocks, quince stocks, raspberries, black currants, gooseberries—together with mangels and potatoes.

During the summer of 1922, most of the nursery material became badly affected with leaf scorch, whilst the haulm of the potatoes which made rapid growth during the beginning of the season collapsed, and the yield of tubers subsequently obtained was poor. In view of these results, a dressing of sulphate of potash at 3 cwts. per acre was applied to the whole area in the following spring, and in 1923 the growth of the trees and bushes was normal and scorch practically absent. Since then, a potash dressing has been given each season and leaf scorch has never recurred. Although no control was left at this centre there seems no doubt that leaf scorch on the area was controlled by potash manuring.

It is possibly opportune at this point to draw attention to the frequency with which leaf scorch occurs on land freshly ploughed out from old turf. Area 25 was such a case, also Areas 35 and 34 and many others can be cited from among the cases discussed in this paper. Scorching in such cases may be aggravated by the " high nitrogen " conditions which result from the decay of the ploughed in turf whilst, as the result of previous management, the available potash is also often undoubtedly low.

Experiment 5.—*Area not given.*

The soil conditions on this area are similar to those on Area 40, sandstone rock occurring at depths varying from nine inches. The centre was visited in 1926 in company with Mr. N. Bagenal, Horticultural Officer, Kent County Council.

Mr. Bagenal had been called in to advise on the condition of the gooseberry bushes on the plot during the previous summer, when it has been observed that the bushes which had been planted two years previously were stunted and badly scorched. The variety is Careless. The advice given was to mulch lightly with dung and to broadcast sulphate of potash over the area at a rate of 3 cwts. per acre. The latter manure was broadcasted as young standard apple trees and plum trees were also growing on the plot. When visited by the writer during the season following the application of the manures, all the bushes were growing well and there was no leaf scorch to be seen.

Experiment 6.—*Area not given.*

This is a further case in which a small area was enclosed from a grass field for nursery purposes. The soil is a sandy loam derived chiefly from the Carboniferous Limestone Formation. The freshly dug area was planted with

gooseberry bushes and these remained scorched and stunted for two seasons. They were then dressed with sulphate of potash at 2 cwts. per acre and in the following year they grew away free from leaf scorch.

GRASS EFFECTS.

Bromyard Area.

In Table VII., containing notes on the leaf scorch areas discussed in the soil section of this paper, four examples of grass orchards located in the Bromyard area are given to illustrate the type of result which is obtained on soil areas falling in Class B2 of Table VIII.

Consideration of these examples will show that on such areas apples, cherries and damsons all fail to make healthy trees and often even fail to become established and die out completely.

It has been shown that attempts to grow apple trees under cultivation on such areas are also almost invariably failures and that in such cases the trees always exhibit leaf scorch. In the grass orchard examples of this kind, of which many have been examined, no case of leaf scorch has ever been observed but, instead, the trees bear small yellowish green leaves which are shed early in the season. In such cases successful trees cannot be grown by "grassing down." Similar results to these are obtained where soil conditions in B1 and B4 are present.

Only one case of a grass orchard comprising any considerable area, coming under B3, has been encountered and in this case standard apple trees of the variety Foxwhelp were stunted and of starved appearance.

Trees under grass on areas B5 and B6 may or may not be successful. Apple trees on such areas appear to be invariably poor and in the more extreme cases are total failures. On the other hand magnificent cherry orchards have been found on such areas and no cases of failures of these have been recorded.

Two cases of apple orchards were examined in this area where deep gravel deposits occur over the sedentary marl. In both cases the orchards had originally been under cultivation but had been "grassed down" because of being unprofitable. Leaf scorch had entirely disappeared in both cases under the grass treatment but the trees had not been successful under ordinary grazing treatment, bearing only poor pale foliage and becoming defoliated early each season.

In one of these cases an attempt is being made to stimulate the trees by intensive "pigging."

Ross Area.

In the Ross area, several opportunities have been provided of observing the effects of "grassing down" on apple trees suffering from leaf scorch under arable conditions. The soil in these cases is of a coarse sandy nature.

An example of the effect of grass in a typical case has been given in Experiment 4 (page 9) in which case it has been shown that the leaf scorch disappeared entirely following "grassing down," but that the trees developed strong symptoms of nitrogen starvation and in consequence were all practically defoliated by the end of July. Two further experimental plots were recorded at this centre at the same time—one on Area 18c—and the results were similar to that above. As stated in Experiment 4, the trees on that particular experimental plot responded markedly to a dressing of nitrate of soda applied during the following spring.

Bunter Drift Area.

The data provided by Experiment 3—Area 22, recorded in Table XIII, show very clearly the effect on leaf scorch of grassing down apple trees on this class of soil. Following grassing down treatment, leaf scorch on the untreated trees fell from 18.5 to 4.5 points. As in cases already mentioned, the treatment caused nitrogen starvation and the trees were defoliated early.

Miscellaneous West Midland Centres.

One of the most successful cases of "grassing down" of badly scorched trees has been observed on Area 30. The trees in question are of the varieties Worcester Pearmain and Cox's Orange Pippin. Previous to "grassing down" several of the trees were in very bad condition, being stunted and severely scorched. The area was sown down with a mixture consisting of perennial rye grass, crested dogstail and wild white clover. Since laying down the grass has been kept short by cutting, the hay being left on the ground. The worst trees have shown gradual improvement under the treatment and during the last two seasons there has been practically no scorch present whilst the trees, although making very little shoot growth, have carried green foliage of good quality and have yielded fair crops. There is no doubt that in this instance production costs have been considerably reduced and the trees have benefited from the treatment.

It has been stated in Experiment 2, page 20, that severe nitrogen starvation has followed "grassing down," whilst it has been possible to control the leaf scorch present at that centre by potash manuring.

S.E. Area.

Two cases of interest require special mention in this district. These occur in connection with Areas 43a and 45. Adjoining each of these areas is a cherry orchard in which areas occur where the soil conditions are similar to those of the leaf scorch areas. In both cases attempts to grow successful cherry trees in these orchards have failed signally hitherto.

At Centres 42a, 44a and 46, " grassing down " has failed as a practical remedy against leaf scorch. The amounts of scorch are possibly reduced but the trees remain stunted and useless.

The above examples will suffice to show the character of the results which may be expected to follow from " grassing down " treatment in cases of leaf scorch.

Their practical significance is discussed below.

Discussion.

The results of the manurial experiments described in this section indicate that in certain cases of leaf scorch a considerable measure of control may be expected from adequate potash manuring and from the use of dung.

In Class A. experiments, beneficial results were obtained in Experiments 1, 2, 3 and 5, and in Experiment 4 the results so far obtained are promising. In Experiments 6 and 7 there is no evidence that leaf scorch can be controlled by potash manures.

The soils in Experiments 1, 2 and 3 are all of the Class 1 type (Table IX) where results might be reasonably expected from potash manuring. In Experiment 5, however, the soil belongs to Class 3 and in such a case one would hesitate to apply potash manures in fruit farm routine. There is evidence in the literature, however, that potash manures may be helpful on heavy soils in wet situations (8).

At the Centre concerned in Experiment 6, there are two possible factors which require consideration—rootstocks and drainage conditions. It was not possible to determine the effects of the manurial treatment here since leaf scorch had disappeared from all plots by the time any result from these would be expected to show. In Experiment 7, in spite of the extremely low "available" potash in the soil, the trees showed no reaction to potash manuring. Possibly the potent factor conducive to scorching is the rootstock.

In all six cases in Class B. experiments, positive results were obtained from potash manuring. The soils in these cases are not all shown in the classification table but would all come under Class 1 (Table IX).

In view of the results obtained in the two series of experiments, it appears worth while for growers to carry out trials with dung and potash manures in cases of leaf scorch on soils of the Class 1 category, and it seems desirable to point out the disastrous results which have occurred on such soils by omitting to apply potash manures when dung has not been available.

No manurial experiments have been carried out to date on soil areas in Class 2.

There are several points of importance attaching to the observations recorded on grass effect.

In the majority of cases, it appears that no advantage will be gained by merely grassing down a leaf scorch plantation. The observations suggest that "grass effect" may be largely due to the substantial lowering of the nitrogen conditions within the tree since in practically every case observed scorched trees have exhibited signs of acute nitrogen starvation immediately following "grassing" treatment. In most cases, the new condition has been as bad if not worse than the old one.

If it is recognised that the trees under grass no longer suffer only from effects due to leaf scorch but also from nitrogen starvation, it should be an easy matter to remedy this latter condition in many cases (Class 1 type), as trees under grass—other conditions being favourable—can easily be supplied with a sufficient amount of nitrogen for their needs by the application of manures such as nitrate of soda. This has been done in Class A. Experiment 4 (p. 9).

Since it has been shown in the pot experiments that leaf scorch may result from too wide a $\frac{\text{nitrogen}}{\text{potassium}}$ ratio, "grassing down" and subsequent manuring with nitrogenous and potassic manures, may be found to be a quick method of restoring growth in badly scorched trees on soils of Class 1 type, as the nitrogen supply can be regulated fairly easily in these circumstances.

All cases of leaf scorch in which soils belong to Class 1 may not be amenable to either manurial treatment or "grassing down." Such cases, however, should be comparatively rare. Area 43a is possibly such a case where the soil may be expected to "dry out" completely during periods of drought. Observations have already been made on "grass effect" in the orchard adjoining this area.

Grass treatment does not appear to be successful at centres in soil Class 2 where unweathered and impervious subsoils occur.

Finally, it would not be expected that beneficial results would follow from grassing treatment in bad cases in soil Class 3. In such cases the first step should be to rectify the defective drainage conditions and, if this is not possible, the area should be regarded as unsuitable for fruit growing.

PART V.—CONCLUSION.

In concluding this paper, it seems desirable to attempt to generalise from the evidence available on certain aspects of the problem of leaf scorch, and to bring together some of the more important points which have been revealed in the investigations and to point to the practical application of some of these.

In the first place, the evidence accumulated is all in support of the view that leaf scorch results from defective nutrition. Much of it also points directly to the development of leaf scorch being brought about by unsatisfactory conditions of water supply within the tissues of the plants.

In direct support of such a view, we have the laboratory investigations of Summers (*loc. cit.*) on the production of leaf scorch by the rapid cutting off of water supply to the tissues of plants, of Barker and his colleagues (*loc.cit.*) on the drying out of root systems of trees, of Mann (*loc. cit.*) on the water content of potassium deficient leaves and the rate of transpiration of such leaves under conditions of relatively high summer temperatures, and of the writer in previous experiments (*loc. cit.*), and in the experiments described in the present paper on the control of leaf scorch by supplying adequate potash supplies either to the growth medium or as a spray to the foliage of potash deficient plants.

The soil conditions almost invariably associated with cases of leaf scorch in the field again suggest unsatisfactory conditions of water supply. The texture is either light and open or the soil is shallow and overlies an impervious subsoil, or drainage is poor and waterlogging occurs. The two former conditions favour deficient water supply in dry periods and the third condition leads to root killing, and, as is well known, only specially adapted forms can thrive under such circumstances.

The evidence now available on the problem should prove of great value to the fruit grower. It is known that different classes of fruits, rootstocks and varieties differ in their susceptibilities to leaf scorch and the grower has in these a fairly wide range of choice. It has been shown that certain soil conditions are conducive to the trouble and in many cases he will be able to avoid planting where such conditions occur. On certain of these soil areas, he may expect to grow fruit trees successfully by suitable manurial treatment, by the use of dung and potash manures and by avoiding excessive applications of nitrogenous materials, but on others all his efforts are likely to prove of no avail.

SUMMARY.

1. Results of previous work on leaf scorch are discussed.

2. An account is given of the investigations on leaf scorch carried out by the writer since 1921. These fall into three groups:
   - *a.* Pot experiments with fruit trees in sand culture.
   - *b.* Soil investigations.
   - *c.* Field experiments on methods of controlling leaf scorch.

3. The following points emerged from the pot experiments:
   - *a.* Apple trees, gooseberry and black currant bushes and raspberry and strawberry plants all invariably exhibited leaf scorch symptoms when fed with nutrient solutions deficient in potassium.

b. Leaf scorch in apple trees was controlled by ensuring sufficiently narrow $\frac{\text{nitrogen}}{\text{potassium}}$ ratios in the nutrient solutions. Leaf scorch never occurred on gooseberry and black currant bushes and raspberry and strawberry plants when fed with a complete nutrient solution and given "leaching" treatment.

c. Leaf scorch resulted on black currant and gooseberry bushes and on strawberry plants when the contents of the pots were not leached periodically.

d. Gooseberry bushes fed with a complete nutrient solution but the roots of which were subjected to waterlogging developed leaf scorch. The symptoms differed in certain respects from those resulting from potash deficiency.

e. Leaf scorch was controlled on gooseberry bushes receiving diets deficient in potassium by spraying the foliage with a 1 per cent. solution of potassium sulphate.

f. Experiments were carried out with varieties of apple trees worked on rootstocks of varying resistance to leaf scorch to see whether differences in susceptibility of varieties and rootstocks would be revealed during the first season under the conditions. The results showed that such differences could not be determined by the method employed in the case of the rootstocks, although some idea of the relative susceptibilities of the varieties was indicated.

4. Soil investigations carried out at forty-six centres are reported.

The salient points of these are as follows:

a. Differences (usually in texture) can generally be detected between soils from adjoining "scorch" and "non-scorch" areas.

b. The soils of the leaf scorch areas with one exception were grouped into three classes:

Class I.—Light soils of poor water-holding capacities and low potash supplies.

Class II.—Close-textured silty soils with relatively unweathered impervious subsoils and occasionally subject to waterlogging.

Class III.—Clay soils with defective drainage.

c. In practically every case the "available" potash in the surface soil wasfound to be relatively small, whilst "available" phosphoric acid showed a wide range of values. The soils included some containing large supplies of carbonate of lime and others showing "lime requirements."

5. Attention is drawn to the various factors which should be considered in cases where control measures are to be attempted and reference is made to results obtained by various workers in previous manurial experiments.

6. Manurial experiments carried out at thirteen centres are described. The manures used were dung and potash.

7. Considerable control was effected at several centres, where the soils are of the Class I. category, by dung and potash manures and at one centre where the soil conditions belong to Class III.

   No experiments were carried out with manures on areas where Class II. soils occur.

   At two centres, one in Class II. and one unclassified, no result was observable from the use of potash manures.

8. Observations on "grass effect" at several centres are recorded. Several examples are quoted in which leaf scorch has disappeared after grassing down. The trees in such cases practically always exhibited symptoms of acute nitrogen starvation and often remained stunted and useless.

9. Instances are quoted from the Bromyard area where Class II. soil conditions occur in which trees under cultivation have exhibited leaf scorch and remained stunted whereas under grass no leaf scorch has occurred but the trees have been, nevertheless, failures and often died out completely.

10. The view is advanced that one of the chief ways in which "grassing down" reduces leaf scorch is by bringing about lowered nitrogen supplies within the tree.

11. "Grassing down" treatment alone will not usually provide a satisfactory remedy in leaf scorch plantations. Suitable manuring with nitrogenous and potassic manures will often be necessary in addition to this treatment. Such treatment is only likely to be useful where Class I. soil conditions occur.

12. Drainage should receive attention at the outset in cases where Class II. and III. soil conditions obtain. Further steps may be necessary, especially on Class II. areas. Further work is required on these.

13. The evidence obtained in previous investigations and in the present investigations is regarded as supporting the view that leaf scorch results from unsatisfactory conditions of water supply within the plant.

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PLATE IV.

Bush apple tree, variety Lane's Prince Albert, age 20 years, growing on a Class A soil area in the Bromyard area.

PLATE V.

Bush apple tree, variety Lane's Prince Albert, age 20 years, growing on a Class B2 soil area adjoining area in Plate IV.

PLATE VI.

Bush apple trees, variety James Grieve, age 12 years, growing on a Class A soil area in the Ross area.

PLATE VII.

Bush apple trees, variety James Grieve, age 12 years, growing on a Class C soil area adjoining area in Plate VI.

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AN ANALYSIS OF THE EFFECTS OF POTASH FERTILIZERS ON APPLE TREES AT EAST MALLING.

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1. Introduction.

"Leaf Scorch" of apple trees has been in evidence at East Malling since the early days of the Station. As long ago as 1919 a careful survey of its intensity was made on the plot discussed in the present paper (the "Pruning Plot"). It was found that trees no more than five and six years from planting showed in many cases somewhat severe leaf scorch. An account of observations on the leaf scorch on this plot and others (up to the beginning of the experiment here described) was published in January, 1925 (1).

The observations on trees in pot culture made by Wallace at Long Ashton, in which he found that the omission of potash appeared to cause leaf scorch (2, 3), suggested that a field experiment should be begun on our plot. Accordingly, in the early spring of 1923, the plot was divided along an east and west line into two approximately equal parts; one half has received applications of sulphate of potash, and the other half has been left untreated as a control. These plots will be referred to below as Plots "C" (control) and "P" (receiving potash from 1923 onwards).

2. Description of Plot.

The plot concerned is that used for the past ten or twelve years for apple pruning experiments. The trees were planted partly in 1913-14, and partly in 1914-15, fourteen feet apart each way, in rows running north and south, each row being confined to a single pruning treatment. A division of the plot along the middle from east to west for the potash treatment gives equal numbers of trees of each variety and under each pruning treatment in each half of the plot. There is, however, no buffer row; the potash application is given to the middle of the alley which divides the plots. Thus some of the trees in Plot "C" (control) are within seven feet of the boundary, and presumably manage to obtain small amounts of the potash. Also some of the trees in Plot "P" (receiving potash) probably have a number of roots outside the potash area. A comparison of the averages with these boundary trees excluded shows that they are frequently altered, but as often in one direction as the other. As the number of trees of any one variety is not very large, the boundary trees are here included.

It is recognised that the arrangement of the plot, from the experimental point of view, is very elementary. This was necessitated by the fact that the

primary purpose of the plot is for a trial of different pruning methods. It was not considered feasible to arrange a satisfactory distribution of small plots to be treated with potash without to some extent interfering with the pruning trials. In any case, as will be seen below, the half of the plot more severely affected by leaf scorch was deliberately chosen for treatment; and the many sets of trees re-duplicate the result to such an extent that a very strong case can be made out.

The actual number of trees is sixteen of each variety on each half of the plot. But as half the trees are leader tipped each year, and the remainder left untipped, it is necessary to regard each sixteen as consisting of two lots of eight trees. The available number of trees is further reduced by the fact that the headland trees on Plot "P" (receiving potash) are close to a poplar windbreak, which has been obviously detrimental to their growth and cropping for several years past.

On the other hand, of the fifteen varieties in the plot, five are in duplicate, one set nominally on "crab" stocks, and the other on "paradise." This fact gives a further means of checking the result, although it must be remembered that rootstock materially affects the susceptibility of a tree to leaf scorch (1).

As stated above, the north half of the plot was selected to receive potash applications, because the trees on the greater part of it had consistently shown more severe leaf scorch than on the other half. The graphs presented below will show how strikingly this was the case. We have, in all, forty sets of trees (twenty untipped and twenty tipped, each consisting of fifteen varieties, five in duplicate). Of the twenty sets of untipped trees, eighteen were either behind or relatively falling off in growth and cropping on Plot "P" (treated) before the treatment began. Of the twenty sets of tipped trees, fifteen were similarly either behind or relatively falling off in growth, and fifteen also in cropping, though not in all cases the same sets.

3. Manurial Treatment of Plot.

Table I. shows in detail the various manures and fertilizers received by the plot from 1919 onwards. Until the spring of 1923 the treatment was identical over the whole plantation. In March of that year, Plot "P" (treated), received its first application of sulphate of potash—approximately 2½ cwts. per acre. Perhaps not altogether unfortunately, the potash treatment was omitted in the spring of 1924; but in March, 1925, it was resumed, and since then sulphate of potash has been applied to Plot "P" each spring, at the rate of 4 cwts. per acre.

In 1925 and 1926 various parts of the plot received somewhat different treatment. It must be specially noted, however, that the trees in any one set have throughout received identical treatment, except where potash has been given to half of them.

In 1924-1925, Plot "4" which consists of trees planted one year earlier than those in Plot "3" (the varieties are in no case the same), received a heavy

Table I.

Manurial Treatments.

Plot		1919.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.
Plot 3. Planted 1914-15.	South (Control).	*February.* London Dung. 15 tons. Flue Dust. 15 cwts.	*January.* Shoddy. 30 cwts. Lime. 10 cwts.	*January.* London Dung. 15 tons. *March.* Bone siftings. 4 cwts.	*February.* London Dung. 15 tons.	*March.* Shoddy. 30 cwts.	*March.* Meat and Bone. 8 cwts. *July 1st.* Meat and Bone. 4 cwts. *July 20th.* Peruvian. 4 cwts.	*April.* East half of Plot only. Meat and Bone. 4 cwts.	*March.* Pig Manure. 16 tons.	*April 8th.* Bone Meal. 13 cwts.
	North (Potash).	London Dung. 15 tons. Flue Dust. 15 cwts.	Shoddy. 30 cwts. Lime. 10 cwts.	London Dung. 15 tons. Bone siftings. 4 cwts.	London Dung. 15 tons.	Shoddy. 30 cwts. *March.* Sulph. of Potash. 2½ cwts.	Meat and Bone. 8 cwts. Meat and Bone. 4 cwts. Peruvian 4 cwts.	East half Meat and Bone. 4 cwts. *April 7th.* Sulph. of Potash. (whole Plot) 4 cwts.	Pig manure. 16 tons. *March.* Sulph. of Potash. 4 cwts.	Bone Meal. 13 cwts. *April 4th.* Sulph. of Potash. 4 cwts.
Plot 4. Planted 1913-14.	South (Control).	London Dung. 15 tons. Flue Dust. 15 cwts.	Shoddy. 30 cwts. Lime. 10 cwts.	London Dung. 15 tons. Bone siftings. 4 cwts.	London Dung. 15 tons.	Shoddy. 30 cwts.	Meat and Bone. 8 cwts. Meat and Bone. 4 cwts. Peruvian. 4 cwts.	*January.* Pig Manure. 17 tons.	*March.* Meat and Bone. 14 cwts.	Bone Meal. 13 cwts.
	North (Potash).	London Dung. 15 tons. Flue Dust. 15 cwts.	Shoddy. 30 cwts. Lime. 10 cwts.	London Dung. 15 tons. Bone siftings. 4 cwts.	London Dung. 15 tons.	Shoddy. 30 cwts. Sulph. of Potash. 2½ cwts.	Meat and Bone. 8 cwts. Meat and Bone. 4 cwts. Peruvian. 4 cwts.	Pig manure. 17 tons. *April 7th.* Sulph. of Potash. 4 cwts.	Meat and Bone. 14 cwts. *March.* Sulph. of Potash. 4 cwts.	Bone Meal. 13 cwts. Sulph. of Potash. 4 cwts.

dressing of pig dung. A similar dressing was applied to Plot " 3 " a year later. In 1925, again, half of Plot " 3," containing six complete sets of trees, received a spring dressing of " meat and bone." Except for these instances, and for the potash treatment, the entire plot has received identical manurial treatment since 1919. It will be observed from the Table that the whole plot received " flue dust " in the early part of 1919. This may well have made the leaf scorch less severe than it would otherwise have been, when the potash treatment began.

4. RECORDS AVAILABLE.

For the purpose of a study of the effects of various methods of pruning, individual tree records have been kept in considerable detail on the entire plot from 1919 onwards, i.e., for four years *before* the potash treatment began on " Plot P," and for the five years since.

The number and weight of fruit, and the weight of prunings removed from the trees that are pruned at all, have been recorded for the whole period. Similarly, the height and spread of the trees, and the girth of their stems have been recorded on Plot " 4 " from the end of 1919 onwards, and on Plot " 3 " from the end of 1920. Several years' records are also available of the number of blossom buds ; but these are chiefly from the tipped trees, since the untipped trees early became so large and complicated that it was impracticable to count their fruit buds.

Detailed records of " leaf scorch " have been kept from the greater part of the plot from 1924 onwards. Unfortunately no comparable records are available previous to 1924. Even those from 1924 onwards are not fully satisfactory, since at best they must be based mainly on an estimate and not on an actual count of leaves. The method employed was to give each tree a mark from 1 to 10, according to the estimated percentage of leaves showing " scorch." Estimates were checked from time to time by means of actual counts on one or two branches. Plus and minus signs were frequently added, and slight cases were marked as T or T–. In 1924, 1925 and 1926, the same two members of the Staff made the whole of the notes. In order to provide a further check on the reliability of their estimates, in 1927 a third member was alone responsible. The result of these estimates is not so satisfactory as could be wished, and by no means shows the real difference between the treated and untreated trees, especially in 1926 and 1927 ; for it is based solely on *number* of leaves affected and takes no account of *degree*. If the degree also could have been estimated, the differences in Tables III. and IV. would be very much larger than they are, at least in 1926 and 1927.

From 1925 onwards the fruit (from each tree separately) of most varieties has been graded into sizes, and the number and weight in each grade recorded. Of certain varieties the fruit has also been colour graded. Finally, the number

of dropped apples, and the number of cuts made in pruning, have also been consistently recorded.

Thus the behaviour of each tree can be studied in considerable detail. But the chief value of the records for the present purpose lies in the fact that it is possible to show the behaviour of the trees for three or four years *before* the potash treatment was begun. Thus, wherever it can be shown that the behaviour of the trees in Plot " P," as compared with that of those in Plot " C " has been reversed since the potash treatment began, we are in a very strong position for concluding that the potash is responsible for the change. This is especially important, in view of the somewhat variable material with which we are working, and also in view of the elementary arrangement of the trial referred to above.

5. Method of Presentation of Records.

The mass of records available is now so great that it is manifestly impossible to present here even the averages of all the figures. It seems best to concentrate on certain representative varieties, and show their behaviour in detail; any of the records can be seen at East Malling Research Station by those interested. The choice of three varieties which show the influence of the potash very clearly will perhaps not be considered unfair, if the behaviour of all those varieties which do not yet exhibit the influence clearly is also shown.

As mentioned above, the records from the " leader tipped " trees must be presented separately from those of the " untipped " trees. Actually the pruning appears to have caused interesting differences in the behaviour of the trees, as far as the potash influence is concerned. With twenty sets of trees, each consisting of tipped and untipped trees, we thus have *forty* comparisons between control trees and potash manured trees.

For purposes of simplicity, the graphs here presented show, not the actual figures for weight of crop, increase in girth, etc., but *the relationship as regards these data* between the trees on Plots " C " and " P " before and after the beginning of the experiment. In all cases the figures for the control trees are taken as 100, and those for the treated trees in proportion. We thus get one curve in place of two ; instead of having to compare the direction and steepness of *two* curves, we compare one curve with the straight line representing the " control " trees, i.e., 100. In brief, wherever the curve falls the trees receiving potash are *falling off* as compared with the control trees ; and, of course, wherever the curve rises the treated trees are gaining, as compared with the control trees. For example, in the graph (Plate I.), showing the weight of crop of Lane's Prince Albert, we find that in 1919 and 1920, the untipped trees (continuous line) on Plot " P " bore 85 per cent. as much weight of fruit as the trees on Plot " C," i.e., they were 15 per cent. behind. By 1922 and 1923 they were over 40 per cent. behind,

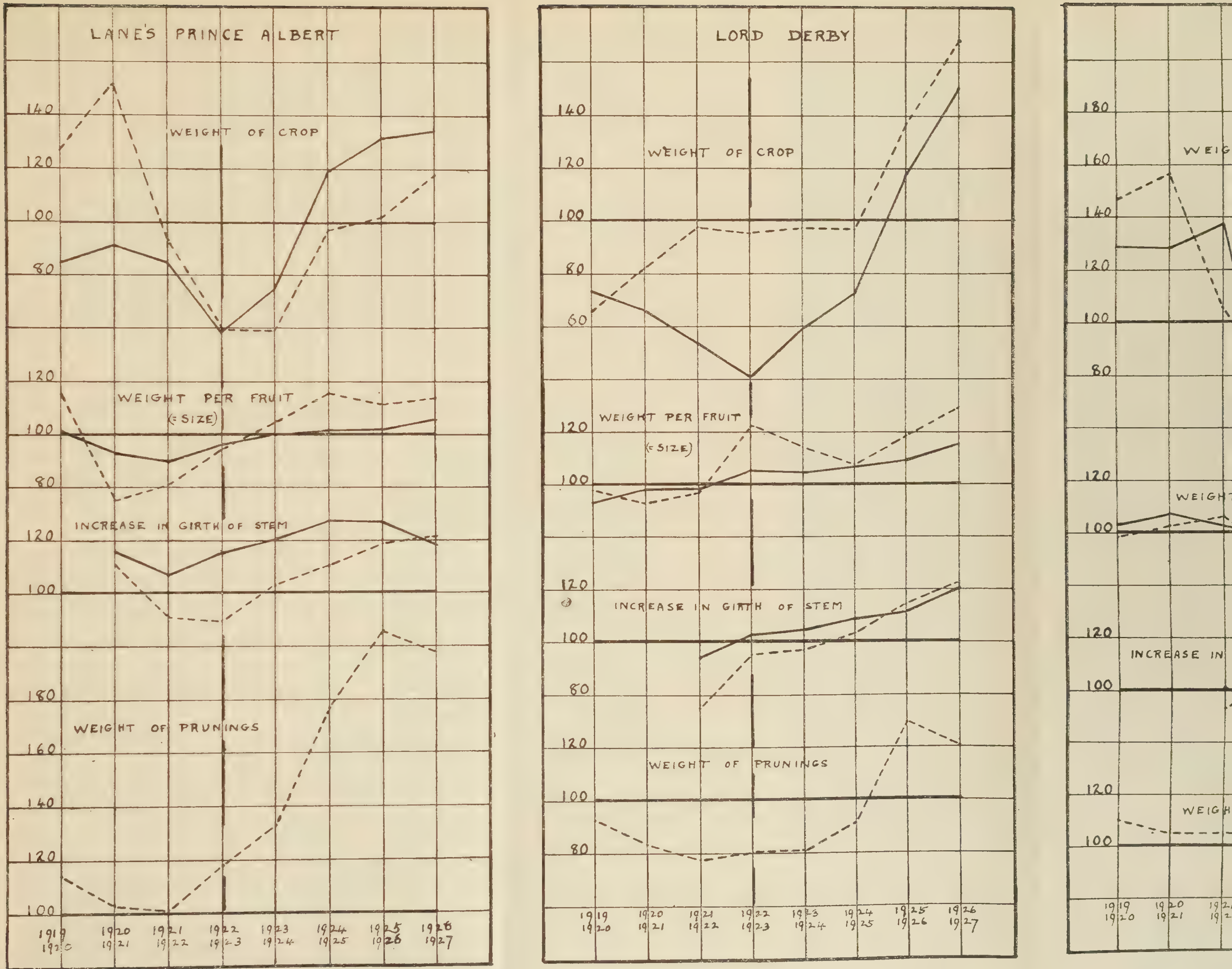

PLATE I.

For explanation of Graphs, see page 59.

whilst in 1926 and 1927 they were about 34 per cent. ahead. Similarly the tipped trees of Lane's (broken line) bore in 1919 and 1920 about 27 per cent. more fruit on Plot " P " ; in 1922 and 1923, and again in 1923 and 1924, they were over 40 per cent. behind on Plot " P," but subsequently improved, until in 1926 and 1927 they were about 17 per cent. ahead.

It must be remembered that as the actual figures are not shown, it is not possible from these graphs to compare the actual behaviour of the tipped and untipped trees. Only their different response to potash manuring can be seen.

It is necessary also to note that in the preparation of the graphs the records are taken in *two year periods*. Owing to the phenomenon known as " biennial bearing " which is very prevalent amongst the trees in this plot, the single year records give extremely irregular curves ; in many cases they are so irregular that the scale would have to be much reduced, and the result would not be obvious at a glance, as it is by the method here employed.

6. Discussion of Results.

It cannot be too strongly stated that all the data on which the results here presented are based, are closely interrelated ; they cannot be regarded independently. It has been known amongst growers for many years, for instance, that a heavy crop usually consists of small fruit, and many growers are now finding it profitable to thin the fruit of certain varieties while still quite small, in order to improve the size of the remainder. Similarly, our data show that there is a close relationship between the amount of fruit borne by the tree (shown by weight of crop), on the one side, and growth (shown by increase in girth of stem, weight of prunings, number of shoots, etc.), and leaf scorch, on the other. A heavy crop checks the growth of the tree, and increases the severity of the leaf scorch. As this point is of some importance, and the writer knows of no published data except those for one year contained in the article already referred to (1), a table is here given by way of illustration. The most convenient trees for this purpose are those which exhibit the biennial bearing habit most clearly. Unfortunately, the vast majority of our trees have their " on year " in the same year : only one set, for which adequate leaf scorch data are available, is divided into two more or less equal sets, cropping in alternate years. These are the untipped trees of Early Victoria on " Crab " stock. Even here only two years records of leaf scorch are available.

The change in the number of trees in the two groups on the " control " plot between 1924 and 1926 is due to the fact that one tree cropped heavily in 1924 and 1925 and had an " off year " (with rather severe leaf scorch, which raises the average figure) in 1926.

The figures indicate how much more severe is the leaf scorch in the " on year ;" they also make it clear that the girth increases more slowly in the " on year."

TABLE II.

RELATION BETWEEN CROPPING, GROWTH AND LEAF SCORCH.

Early Victoria, on "Crab," untipped.

	1924.				1926.			
	Number of Trees.	Average Weight of Crop. lbs.	Average Increase in Girth. mm.	Average per cent. of leaves scorched.	Number of Trees.	Average Weight of Crop. lbs.	Average Increase in Girth. mm.	Average per cent. of leaves scorched.
"CONTROL" PLOT. Cropping ("on year") ..	6	72	17	78	5	79	20	40
Not Cropping ("off year")	2	5	27	10	3	8	25	24
RECEIVING POTASH:								
Cropping	5	97	18	68	5	87	35	5
Not Cropping	3	14	37	24	3	1.5	42.5	0.7

It is fairly clear then, that, other things being equal, we may expect a relative increase in crop to be accompanied by smaller fruit, by more severe leaf scorch (where leaf scorch is present at all), and by a smaller increase in girth of stem; and we might also expect to find a relatively smaller wood growth (as shown by weight of prunings, number of shoots, etc.). Though our plot is arranged in such an elementary way, and though the rootstocks are in several cases known to be mixed, apart from these factors everything possible has been done to make "other things equal" between Plots "C" and "P," except in regard to potash manuring.

7. THREE TYPICAL EXAMPLES.

Let us then see how our trees are behaving. We will take first three varieties which show the influence of the potash as well as any, Lane's Prince Albert, Lord Derby and Rival. Plate I. shows in graph form the relationship between the treated and untreated trees as regards weight of crop, size of fruit (weight per fruit), increase in girth of stem, and weight of prunings. The records on leaf scorch are too scanty and the intensity of the leaf scorch varies too much from year to year, to allow of their satisfactory presentation in graph form; they are therefore shown in Table III.

Let us take first the untipped trees, shown in the graphs by the continuous line. We shall find that, up to the time of the first application of potash, the trees of all three varieties on Plot "P" had been relatively falling off in weight of crop; two of them also, (Lane's and Rival), either had been, or were, relatively falling off in rate of girth increase. Yet either concurrent with the first application of potash or a year later, the curve begins to rise, and not only that for weight of crop, but also that for girth increase. At the same time, as shown by Table III., the percentage of scorched leaves was materially reduced between 1924 and 1926 or 1927, though owing to the varying intensity of the scorch from year to year, the reduction is somewhat irregular. It may be remarked here that, in general, no reduction in the intensity of leaf scorch was noticeable until after the second application of potash; after the third it was quite obvious. Thus we have the trees receiving potash (untipped) improving in all respects as compared with the control trees. The case of the tipped trees (shown in the graphs by the broken lines), is essentially similar, though it is complicated by certain phenomena which will be discussed later.

In the curves showing "weight per fruit" a somewhat similar state of things can be seen. But in the case of the untipped trees of Lord Derby the curve begins to rise before the first application of potash was made. Doubtless this is due to the further fall in weight of crop, which was already relatively low. In this and another case, Lane's, the curve showing "weight per fruit" rises with the

TABLE III.

Estimated Percentage of Leaves showing " Leaf Scorch."

	Lane's Prince Albert.				Lord Derby.				Rival.			
	1924.	1925.	1926.	1927.	1924.	1925.	1926.	1927.	1924.	1925.	1926.	1927.
UNTIPPED :												
Control " C "	31	2	12	not re-corded	64	54	67	89	61	55	15	not re-corded.
Receiving Potash " P "..	30	2	3	—	69	51	34	60	61	70	13	—
TIPPED :												
Control " C "	12	2	11	—	66	52	77	87	33	29	16	—
Receiving Potash " P "	7	1	4	—	72	19	25	65	33	25	3	—

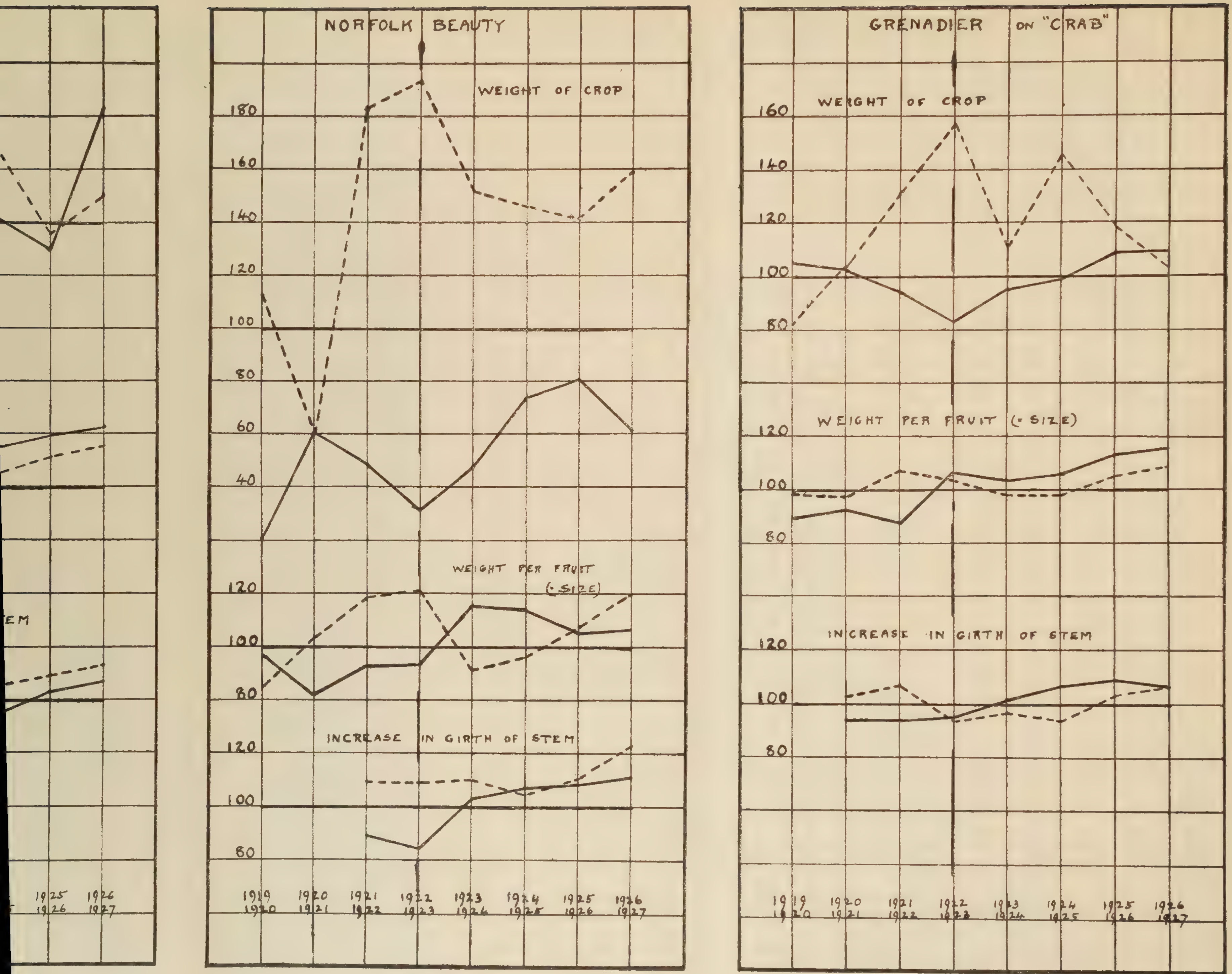

PLATE II.

For explanation of Graphs, see page 59.

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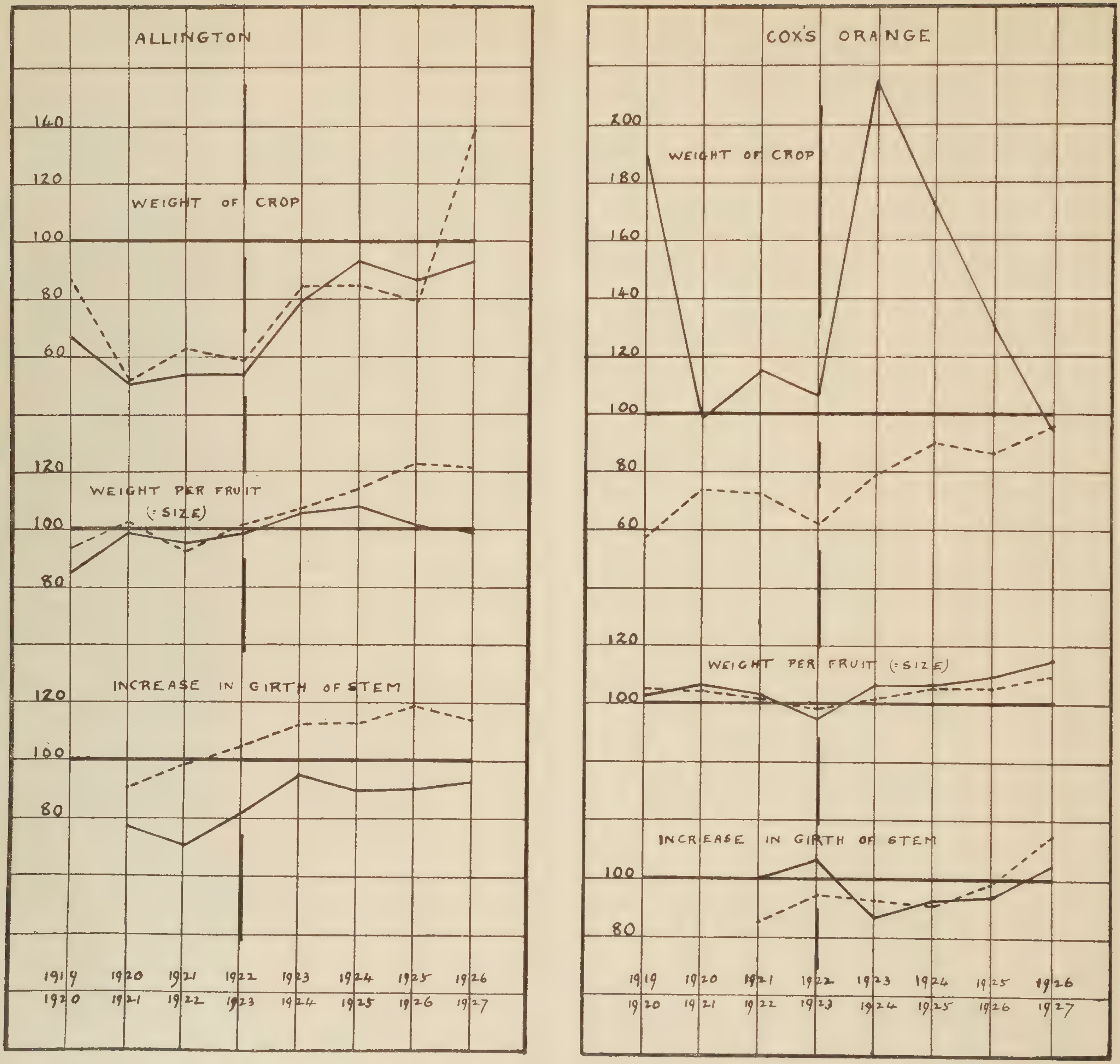


PLATE III.
For explanation of Graphs, see page 59.

first application of potash ; as the application was made in March of the year (1923) this need not occasion surprise.

We find then this state of affairs. Even where the trees in Plot " P " were, prior to the beginning of the treatment, relatively falling off in cropping, size of fruit, and growth (as shown by girth of stem and weight of prunings), within a year of the first application of potash they were all relatively improving, and in most cases the improvement has gone on steadily and rapidly to the present time. In *every* case at the end of the period (1926 and 1927 together) the curve is well above the 100 line, although in every case but one (girth increase of Lane's untipped) it had at one time or another been below 100.

It must be remembered also, that the potash application was omitted in 1924 ; thus any rise in the curves previous to 1924 and 1925 must have been brought about solely by the one application ($2\frac{1}{2}$ cwt. per acre only), of 1923.

8. Exceptional Cases.

The three varieties here presented show this influence of potash as clearly as any. Several others, however, show it almost equally strikingly, Beauty of Bath, Grenadier (on " Paradise ") and James Grieve (on both " Crab " and " Paradise "), being perhaps the most noteworthy. There are only five apparent exceptions to the rule, and these are but partial: the tipped trees of Norfolk Beauty, Grenadier (on " Crab ") and Annie Elizabeth, and the untipped trees of Allington and Cox's Orange. Of the forty possible comparisons between trees on " Plots C " and " P ", therefore, we have but five apparent exceptions to the rule, and of these five three may be susceptible of a fairly simple explanation. Graphs for the five sets of trees concerned, both tipped and untipped, are presented in Plates II and III.

In the cases of Grenadier (on " Crab "), Norfolk Beauty, and Annie Elizabeth, it is the *tipped* trees that do not show the potash influence clearly ; and it is only in cropping that they do not show it ; size of fruit, and increase in girth, both show it clearly, and weight of prunings also, though less clearly. Unfortunately the leaf-scorch records are here incomplete ; as far as they go, however, they all show (Table 4) that the potash has reduced the leaf-scorch proportionately more in the case of the *untipped* than the *tipped* trees.

In the case of Grenadier the explanation may lie in the stocks on which the trees are worked. It has been shown (1) that " crab " or seedling stocks show a very high degree of variability in the susceptibility to leaf-scorch which they induce in the scion. It may be that this great variability has here tended to obscure the normal result.

9. May Potash Treatment in some cases delay Cropping ?

Another explanation is possible for all these cases, and there is considerable other evidence to bear it out. It has been observed by Wallace (and others)

that in extreme cases of leaf-scorch the tree produces very little growth and very large numbers of fruit buds. Presumably, then, a gradually developing attack of leaf-scorch would tend to make a young tree bear fruit more quickly than would a normal tree of the same age. And it is quite conceivable that a dose of potash applied at a certain stage of the trees' growth might, by curing leaf-scorch, tend to *throw the tree out of bearing*. No doubt this is a very unorthodox suggestion, but it will be worth while to present what evidence our trees can produce, for and against it.

It has repeatedly been shown, by Pickering (4) and later workers, that pruned trees, or at any rate leader-tipped trees, come into bearing more slowly than unpruned trees. Let us, then, examine the behaviour of our tipped and untipped trees as regards the influence on fruit bearing of the more severe leaf-scorch on Plot " P " before the treatment began, and of the subsequent potash treatment. We might expect that, previous to the treatment, the trees on Plot " P," being more severely affected by leaf-scorch, would in some cases come into cropping more quickly than those on Plot " C " ; and that since the trees were five and six years old from planting when our records began, this would be shown more distinctly by the tipped trees (they being slower to crop), than by the untipped. This is precisely what we find.

It may perhaps be suggested that, since leaf-scorch is known to decrease the size of the fruit, and our potash treatment has certainly increased it, and since any change in size of fruit will obviously be reflected in the weight of the crop, a graph showing the relative number of fruits would be more reliable for this purpose than one showing weight of crop. Such graphs have been made for every set of trees in the plot. They differ slightly from those for weight of crop, as would be expected ; in general, the curve previous to the application of potash is steeper, and afterwards less steep. But in no case is the difference considerable enough to vitiate the argument which follows.

In the graphs showing weight of crop, wherever the curve begins or rises above the 100 line the trees on Plot " P " were, of course, cropping more heavily than those on Plot " C " ; and where the broken line is above the continuous line, this was more marked in the case of the tipped trees than the untipped. And further, if the curve rises, the effect is becoming more pronounced. In the graphs here presented (Plates I., II. and III.) only Rival shows both curves above the 100 line at the beginning. But Lane's, Allington, Annie Elizabeth and Norfolk Beauty all show the curve for the tipped trees above that for the untipped at the beginning ; and in the cases of Lane's, Lord Derby, Rival, Allington, Annie Elizabeth, and Grenadier (on " Crab "), the curve for the tipped trees rises whilst that for the untipped trees is either falling or rising less steeply. Even in the case of Norfolk Beauty, the curve for the tipped trees, after falling steeply at first, then rises still more steeply, whilst that for the

untipped trees, after an initial rise, is falling more or less. A summary of the twenty sets of trees shows that in no less than sixteen cases the curve for the tipped trees behaves in this way in the early years, either rising more steeply or falling less steeply than that for the untipped trees. In three of the remaining four cases, the curve for the tipped trees starts well above that for the untipped trees, although it falls equally or slightly more at first.

It seems quite probable, then, that the greater severity of leaf scorch on Plot " P " (previous to the treatment) did tend to bring the trees into bearing more quickly than those on Plot " C." Now let us see what happened after the potash treatment was begun. We should expect that, if the potash treatment has any tendency to throw the trees out of bearing, this would be shown most clearly by those varieties which are normally slow to crop, and more clearly by the tipped than the untipped trees, i.e. the curve for the tipped trees should fall, or be slower to rise, after the application of potash, than that for the untipped trees. This is the general tendency of our records, though here again there are exceptions. Compare, for instance, the cropping of the tipped and untipped trees (as shown by the graphs) of Norfolk Beauty and Annie Elizabeth, after the beginning of the potash treatment. Both these varieties are slow to crop, Norfolk Beauty particularly so in the case of the tipped trees. The trees of Annie Elizabeth, moreover, are two years younger than the other trees in Plot " 3," and three years younger than those in Plot " 4." In each case we find that in the second biennial period which includes the first application of potash (1923 and 1924), the line for the tipped trees falls, whilst that for the untipped trees rises. Although there are irregularities, this tendency continues in each case down to 1925 and 1926 in the case of Norfolk Beauty, and to the last period in Annie Elizabeth. Note also how in the case of Lord Derby and Lane's the line for the tipped trees is slower to rise after potash applications began than that for the untipped trees. The delay in cropping caused by tipping was specially marked in the case of Lane's. The same tendency is shown by Early Victoria (on " Paradise "), Grenadier (on both " Crab " and " Paradise "), James Grieve (on " Paradise "), Gladstone (on both " Crab " and " Paradise "), and Worcester Pearmain (on " Crab "). It is inconspicuous or doubtful in the cases of Cox's Orange, Allington, Rival (see graphs), Bismarck, James Grieve (on " Crab "), and Beauty of Bath ; and it appears to be reversed in the cases of Early Victoria (on " Crab "), Worcester Pearmain (on " Paradise "), and Newton Wonder. Of these last three, the case of Newton Wonder is open to a simple explanation. Two particular tipped trees in Plot " C " did not begin to crop reasonably heavily until 1926 ; and in 1926 they both bore a very heavy crop. The result is that the curve for the tipped trees in general rises until these two trees begin to crop, and then falls heavily. Meanwhile one particular untipped tree in Plot " C " cropped heavily each year, whilst all the rest (tipped and untipped) were bearing

TABLE IV.

Estimated Percentage of Leaves showing "Leaf Scorch."

	Grenadier on "Crab."			Norfolk Beauty.	Annie Elizabeth.	Allington.				Cox's Orange.			
	1924.	1925.	1926.	1926.	1926.	1924.	1925.	1926.	1927.	1924.	1925.	1926.	1927.
UNTIPPED:													
Control "C"	60	26	36	39	78	63	25	18	64	67	25	21	67
Receiving Potash "P" ..	56	15	12	10	30	65	30	19	54	47	1	3	35
TIPPED:													
Control "C"	8	6	16	39	44	50	45	20	85	54	52	54	76
Receiving Potash "P" ..	25	17	13	23	26	45	26	14	49	53	36	17	30

crops only in alternate years. Consequently the curve for the untipped trees is slower to rise ; but when it does rise, it rises steeply. The number of trees in our plots is not large enough to eliminate the effect on the averages of such exceptional trees as these.

On the whole, the weight of evidence seems to support the unorthodox suggestion made above, that potash manuring may in some cases tend to throw trees out of bearing. Readers who are interested in the bearing such a tendency might have on commercial practice will find this point discussed in a later section. If the tendency exists, it may be due either to a checking of the formation of fruit buds, or to the reduction of the proportion of blossoms which produce fruit. It is also conceivable, though hardly likely, that some of the evidence adduced above may be due to an influence of the potash causing a relatively lighter set of the blossom on the tipped trees than on the untipped trees.

The other two apparent exceptions are much more puzzling. In the case of Allington, the tipped trees (shown by the broken line in the Graph) show the potash influence clearly, especially in the very big rise in weight of crop in the last biennial period. True, this is accompanied by a slight falling off in both size of fruit and girth increase ; but in spite of the immense relative increase in crop, since in both cases the curves remain above the 100 line, the treated trees continue to bear the larger fruit, and to show a larger increase in girth.

The untipped trees show a considerable relative rise in all three respects soon after the first application of potash ; but subsequently there is some falling off, especially in size of fruit ; and it is to be noted that, since the curves are still below the 100 line, the treated trees have not yet come up to the untreated either in weight of crop or girth increase, and have fallen just below in size of fruit. No satisfactory explanation of this exception to the general rule seems to be available.

A still more unaccountable exception occurs in the case of the untipped trees of Cox's Orange. (The tipped trees, as in the case of Allington, give the normal result). Here the trees on Plot " P " show a prodigious relative rise in weight of crop in 1923 and 1924, followed by a steep and steady falling off for the three succeeding biennial periods. The crop of the treated trees, in the last biennial period (1926 and 1927) was relatively at the lowest point it has ever reached, and this in spite of the fact that the leaf-scorch (Table IV.), has been largely reduced by the potash treatment. (It is worth noting, however, that, in the cases of both Allington and Cox's Orange, the leaf-scorch has been more reduced by the potash treatment on the *tipped* than the *untipped* trees.) The treated trees show a slight improvement in both size of fruit and increase in girth, though hardly as much as might have been expected, even without the potash treatment, considering the falling off in their crops.

In the case of Cox's Orange, the "Unpruned" and "Regulated" rows (both of which are included in the "untipped") have behaved similarly; both show a great relative increase in crop on the treated trees in 1923 and 1924, followed by a heavy falling off. It may be said, perhaps, that the method of presentation here employed exaggerates the rise in crop weight of the treated trees in 1923 and 1924. Actually the crops in those two years were very light, amounting for the two years together to but 5½ lbs. per tree on Plot "C" and 12 lbs. per tree on Plot "P." But the relative fall in crop weight of the treated trees in 1925 and 1926, and again in 1926 and 1927, is not exaggerated. Examination of the blossom records shows that the great rise in cropping of the treated trees in 1923 and 1924 was not due to any relative increase in number of fruit buds, but to a much heavier "set" of fruit.

In this case also no satisfactory explanation of the exception can yet be attempted. It is especially curious that these, the only two exceptions amongst the twenty sets of untipped trees, should occur in varieties as closely similar as Allington and Cox's Orange. One cannot escape the conclusion that they are due to the same cause, and not purely accidental, even though it is impossible as yet to guess what the cause may be.

10. Fruit Bud Formation and Setting of Blossom.

It is unfortunate that our records of the number of fruit buds produced by our trees are not complete enough to throw any clear light on these questions. As far as they go, they do not seem to follow any definite rule; except that an increase in the number of fruit buds is very frequently accompanied by a reduction in the proportion which produce fruit. But there are a few striking exceptions.

In the case of Lord Derby, for instance, the records available seem to lead to a definite conclusion. While the potash may to some extent have slightly reduced the formation of fruit buds on both tipped and untipped trees, it seems greatly to have increased the proportion of blossoms which produced fruit (i.e., the "set" of fruit). In the case of Annie Elizabeth the tendency of the potash to reduce the formation of fruit buds again seems to be present in the untipped trees, and possibly in the tipped trees; the "set" of fruit, however, seems to have been increased by the potash in the case of the untipped trees, and reduced in the case of the tipped trees. Bismarck, again, seems to show hardly any tendency for the potash to increase or reduce the formation of fruit buds; but the "set" of fruit does seem to have been materially reduced, in the case of both tipped and untipped trees. The tipped trees of Lane's seem to show that, though the potash had little influence on fruit bud formation, it probably at first reduced the "set" of fruit. The records from the remaining varieties are either too incomplete or too irregular to indicate any possible result.

It can only be suggested, then, that where leaf-scorch (or other evidence of potash deficiency) is present, applications of potash *may* possibly influence both the formation of fruit buds, and the " set " of fruit, but that such an influence, if it exists, is likely to vary with the variety and the pruning treatment, and perhaps also with the root stock and the age of the trees.

11. VARIETIES RESISTANT TO LEAF-SCORCH.

It may be asked, is potash likely to influence trees of varieties, or worked on root stocks, not usually very susceptible to leaf scorch ? The outstanding case is, of course, that of Worcester Pearmain, which, as has been shown (1), is the least susceptible to leaf-scorch of all the fifteen varieties in the plot. Throughout the recorded period, there has not been a single tree of Worcester Pearmain, out of the sixty-four available, which has been estimated as showing more than 50 per cent. of scorched leaves, and extremely few with more than 30 per cent., and the degree of leaf scorch has always been slight. In years when leaf scorch has not been unusually severe, the majority of the trees have been marked as entirely free from scorch.

Since potash applications began, however, what little leaf scorch the Worcester Pearmain trees have shown has been mainly on Plot " C." Considering how very slight this has been, it is surprising to find how clearly both sets of trees of this variety (on " Crab " and " Paradise ") show the influence of potash, in both cropping and growth. In comparison with Rival, perhaps, the influence may not be considerable ; the tipped trees of Worcester (on " Paradise ") on Plot " P," for instance, show a relative rise in crop from a 40 per cent. deficiency to a 34 per cent. surplus as compared with those on Plot " C,"—and this is the extreme. Yet there can be no doubt that the influence is there. It is also clear in the size of the fruit, which in the case of the trees on " Crab," both tipped and untipped, has improved from 10 per cent. smaller to from 6 per cent. to 10 per cent. larger. We can say definitely, then, that in the case of a soil like ours, where trees frequently show leaf scorch, even such a resistant variety as Worcester Pearmain is benefited by potash.

Our present plot does not provide enough data to show whether trees on root-stocks not usually associated with leaf scorch are benefited by potash or not. The " Crab " stocks are much too variable to give any possible indication ; and the varieties of " Paradise " so far identified are almost always those associated with scorch. There is but one instance where trees known to be on the resistant " No. III." (" Hollyleaf ") occur in both the treated and untreated parts of the same row. This is in the " Unpruned " row of Beauty of Bath. It happens that a comparison of these two trees gives a result very similar to that for the whole series of untipped trees of Beauty of Bath ; since the treatment began, the treated tree has considerably improved in cropping as compared with the untreated

tree (though with one heavy fall in the biennial period 1925 and 1926); and, in increase in girth of stem, after falling much behind, before the treatment began, it has gone still further ahead. Little importance, however, can be attached to such a result. It is at any rate safe to say that trees on stocks not associated with leaf scorch will show less benefit from potash treatment than trees on such stocks as, for instance, the Doucin (No. II.), the Doucin Ameliorée (No. V.), and the nameless No. VII.

12. Colour of Fruit.

The records on the colour of the fruit are far from complete, even for the highly coloured varieties. No colour grading was done until 1925; the writer is indebted to Mr. W. S. Rogers for records made by him in that year on the varieties Allington, Cox's Orange, and Lane's Prince Albert. In 1926 similar records were made of the fruit of Allington and Rival; and in 1927, of Allington, Cox's Orange, Rival, and Worcester Pearmain (on "Crab").

The results are summarised in Table V. It seems best in this case to present the results from each pruning treatment separately; for, in the first place, the records of Allington and Cox's Orange made in 1925 covered only three of the four pruning treaments; and in the second place, if the density of the tree affects the fruit colour at all, we should expect a different colour development from the two untipped rows, the "Unpruned" and "Regulated" trees, of which the former are in most cases considerably more dense. It is less likely, though still possible, that the difference in pruning treatment between the "Long spurred" and "Short spurred" (tipped) trees would affect the colour of the fruit. The fruit of Worcester Pearmain (1927) was picked over once, and cleared later; since only the best coloured fruit was taken at the first picking, it seems best to give the figures for the two pickings separately. We should expect any influence of the potash to show more clearly in the *second* than in the *first* picking.

All the figures represent the average percentage of the surface of the fruit which showed more than a trace of red colour. The method employed was essentially the same as that described by Rogers (5), and consisted of separating the fruit into four grades according to whether more or less than one, two, or three quarters of the surface were coloured.

The Table gives us, in all, thirty-eight comparisons of treated and untreated trees. The differences are often small, but in several cases appear large enough to indicate a definite cause. If we include only those where the difference is more than 10 per cent. of the smaller figure (shown in heavy type in the Table), we have eighteen differences left, of which five show that the colour was higher on Plot "P," and thirteen on Plot "C." So far, then, the indication seems to be that the colour was generally less intense on the trees receiving potash.

TABLE V.

Colour of Fruit. Percentage of Surface Coloured.

	Allington.			Cox's Orange.		Lane's Prince Albert.	Rival.		Worcester P. on Crab, 1927.	
	1925.	1926.	1927.	1925.	1927.	1925.	1926.	1927.	1st pick.	2nd pick.
UNTIPPED:										
"Unpruned"										
Control "C"		12.1	17.8	48.7	40.8	15.2	43.6	52.8	53.0	36.7
Treated "P"		12.8	19.9	52.6	44.5	13.0	34.2	44.6	53.7	37.9
"Regulated"										
Control "C"	43.8	21.1	22.0	42.8	38.8	14.6	44.8	42.8	44.8	42.7
Treated "P"	40.3	24.4	22.2	51.0	36.6	11.6	47.8	37.0	47.3	43.9
TIPPED:										
"Long Spurred"										
Control "C"	35.4	20.8	16.7	—	36.8	10.6	37.7	37.7	51.1	38.6
Treated "P"	33.7	18.8	16.2	—	38.2	9.1	34.7	30.8	53.4	37.7
"Short Spurred"										
Control "C"	27.7	24.6	19.8	34.8	38.2	14.2	43.1	40.0	54.8	42.4
Treated "P"	27.8	17.3	17.1	43.6	44.3	11.0	43.6	34.5	50.4	34.1

But if we separate the tipped from the untipped trees, we find a somewhat different result. Of the eight differences of 10 per cent. or more amongst the untipped trees, five show a higher colour on Plot " C," and three on Plot " P." In the case of the tipped trees, we find eight such differences showing a higher colour on Plot " C," and only two on Plot " P." Further, the latter two are both on Cox's Orange ; the other difference from the tipped trees of this variety, though less than 10 per cent., is in the same direction. The results would indicate, then, that whereas the potash has had little if any influence on the colour of the fruit of the untipped trees, it has tended to *reduce* the colour of that of the tipped trees.

But we cannot at once say that there is any *direct* influence of the potash on fruit colour. Colour is undoubtedly influenced by very many factors, amongst them being probably the density of the head of the tree, and particularly of the foliage, and the heaviness of the crop of fruit,—the fruit, of course, being less intensely coloured where the foliage is dense or where the crop is heavy. Now we have already seen that our potash applications have much reduced the leaf scorch, and in most cases have much increased both the crop and the wood growth (as shown by weight of prunings) ; i.e. by making the foliage more dense and the crop heavier, they have tended indirectly to *reduce the colour of the fruit*. Further, eye judgment suggests that the increase in density of the foliage, caused by the potash, is relatively much greater in the case of the tipped than the untipped trees. No satisfactory method of recording this density of foliage has yet been devised. In its absence we can only say that the apparently more noticeable reduction of colour, caused by the potash, on the tipped trees than the untipped, is probably connected with their relatively greater density of foliage.

It seems not unlikely that, if other things were equal, potash might actually heighten the colour of the fruit. Considering that there are several cases where the untipped trees show a higher colour when treated with potash, in spite of denser foliage, and (in the cases of Rival and Worcester Pearmain) heavier crops, we are probably justified at least in assuming that potash does not *directly* reduce the colour. It is of interest, however, to notice that, as far as the untipped trees are concerned, *all but one* of the differences in the table which show the treated fruit to have had the higher colour occur either in Worcester Pearmain, which is highly resistant to leaf scorch ; or in Allington, or Cox's Orange, the untipped trees of which, as we have seen, do not so far show the usual increase in crop due to potash. The one exception, in Rival, is a rather small difference, and is much outweighed by three large differences in the other direction.

13. Maturity of Fruit.

During the fruit picking season of 1927 several pickers thought they noticed that the fruit of the trees on Plot " P " separated from the trees more easily

than that of the trees on Plot "C." Several varieties were included in this observation, and in one or two cases, particularly Worcester Pearmain, the pickers seemed quite certain that there was a very distinct difference. If this is not the result of mere chance variation from tree to tree, it must presumably point to an influence of potash in hastening the maturity of the fruit. No observations have so far been made on the keeping quality of the fruit. But any such influence might be reflected in either the proportion of the crop of early dessert varieties picked at each picking ; or in the proportion of the whole crop which fell from the tree before picking, i.e. the proportion of "windfalls."

The fruit of four varieties,—Beauty of Bath, Gladstone, James Grieve, and Worcester Pearmain,—has usually been "picked over" one or more times before the trees were finally cleared. Since there are two sets of each of the last three varieties, we have seven sets of trees in all available for comparison. The period from one picking to the next has often been very irregular, being governed partly by the weather, and partly by considerations of marketing the fruit. Yet it has been possible to divide each year's picking roughly into two or three equal periods, and thus to work out the relative earliness of ripening on Plots "C" and "P." In the cases of Beauty of Bath, Gladstone, and Worcester Pearmain, there is good evidence that the earlier pickings have been relatively heavier on Plot "P" ; but since the evidence is just as strong for the period prior to 1923, when Plot "P" received its first application of potash, as afterwards, it is unfortunately impossible to attach much importance to the result. There may be, in one or two cases, a slight increase in the relative earliness of picking on Plot "P" from 1923 onwards ; but in the case of James Grieve, there appears to be a slight tendency the other way. It is not worth while, therefore, to present any of these results in tables or graphs.

The number of dropped apples, or windfalls, has been separately recorded from fifteen sets of trees since 1920, and from the remainder since 1921. Graphs prepared in the same way as those in Plates I., II. and III., showing the relative proportion of the crop which dropped before picking on Plots "C" and "P," give a very definite though rather curious result. The graphs for the varieties Lane's Prince Albert, Lord Derby, and Rival are shown in Plate IV.

We have here six curves, three for the untipped trees and three for the tipped. In *every* case we find a marked relative rise in the proportion of windfalls on Plot "P," either in 1922 and 1923, or in 1923 and 1924, although in every case but one (Rival tipped) the proportion had previously been falling. But this rise is followed in every case by some further fall, and in four of the six cases the curve ends below the 100 line, although five of the six had been above the line subsequent to the first potash application. These graphs are typical of those of the great majority of the forty sets of trees (twenty untipped, and twenty tipped). Fourteen of the twenty curves for untipped trees, and fourteen of the twenty

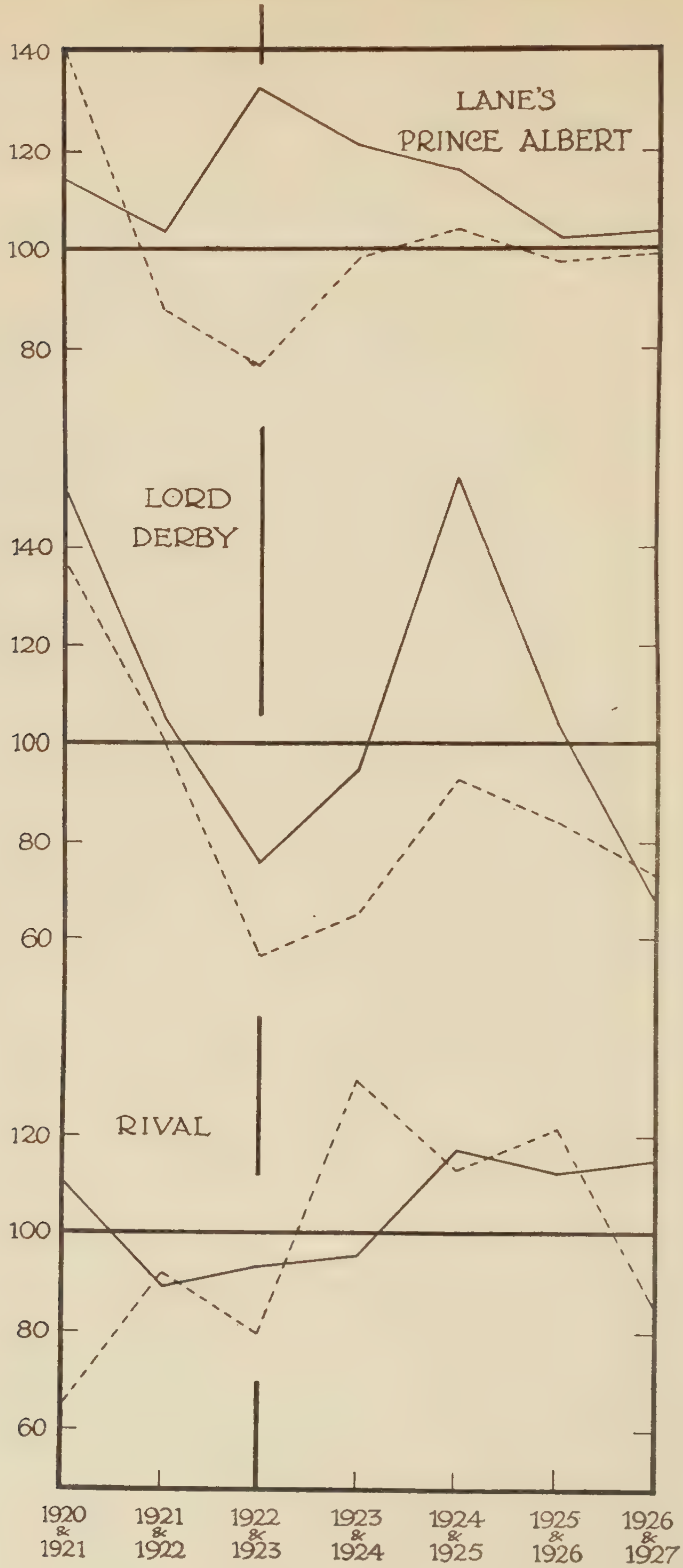


Plate IV.—For explanation of Graphs see page 59.

for tipped trees (not in all cases the same varieties) fall and then rise as in the examples given ; and in four other cases of untipped trees, and five of tipped trees, the curve rises in the same way without a preceeding fall. After the rise, there is a fall (as in the examples given), in no less than seventeen sets of untipped trees and eighteen of tipped trees.

Even those few curves which do not conform to the general plan show some signs of a similar behaviour. Where the curve was rising previous to the application of potash, the rise becomes steeper, and where it was falling the fall becomes less steep. There seems every probability, then, that the application of potash did at first increase the proportion of windfalls, presumably through hastening the maturity of the fruit. It is difficult to explain the subsequent fall in the proportion of windfalls, especially in such a case as that of Lord Derby, where the fall took place, from both untipped and tipped trees, during the years of the last three applications of potash. Six of the curves for the untipped trees, and seven of those for the tipped trees, show a second rise (as in the case of Lane's Prince Albert), which, except in the case of Gladstone (on " Paradise ") untipped and tipped, occurs only in the last period, 1926 and 1927. It seems probable that the influence of the potash is in some way being obscured by other factors. Seasonal influences, and particularly the direction of the prevailing winds, have probably something to do with this. It has been said above that Plot " P " is nearer than Plot " C " to the poplar windbreak, which runs along the north side of plantation. It has frequently been noticed in the late summer and autumn, that, after a strong wind from the north, there are few windfalls near the windbreak ; whilst, after a gale from the south or south west, the number near the windbreak is often larger than elsewhere.

Another factor which may possibly have clouded the result in the cases of certain varieties, is the number of fruits borne in clusters. If the potash has in some cases increased the proportion of the blossoms which " set " fruit, there will presumably have been more fruits in clusters of two or more on Plot " P " than on Plot " C." Now it is known that in the case of short stemmed varieties, like Lord Derby, these clustered fruits tend during their growth to force each other off ; there would thus be a higher proportion of " windfalls " on Plot " P." Our data are not at present full enough to show whether this is happening or not.

But these facts will not explain the peculiar similarity of the curves for early and late varieties, and for short and long stemmed varieties. We find the curves for an early variety like Early Victoria (on both " crab " and " Paradise "), of which the fruit is always picked in July or early August, almost precisely like those for Lord Derby (picked in mid to late September), and not unlike those for Lane's Prince Albert (picked usually in October). Until this experiment can be repeated, with plots so arranged as to eliminate

the effect of local conditions, or to allow of their being accurately estimated, it will not be possible to say how far these peculiarities in behaviour have been brought about by the potash treatment, and how far by other influences.

14. The Economic Aspect.

Those readers who are themselves growers will undoubtedly wish to know to what extent the applications of potash have increased the cash returns from Plot "P." Records of the market price at which the bulk of the fruit (apart from windfalls) was sold are available from 1922 onwards. Until 1925, however, the fruit from Plots "C" and "P" was not graded separately; thus the comparative value of the fruit on the two plots has to be estimated from its average size. The estimate here made is probably fairly accurate. And from 1925 onwards the gross value of the crop from each plot can be calculated exactly; the fruit from each tree was size graded separately, at first by a Westwick slot Grader, and later by a "Cutler," and was marketed in the grades as recorded. Table VI. gives the results of these calculations for the three varieties used as examples above, in bushels (40 lbs.), per acre, and in value. The value represents the actual cash return, after deducting carriage and commission. It will be understood, of course, that these figures are far from showing even the gross profit; it would be necessary to deduct from them not only the cost of picking and packing the fruit, but also that of all cultivations, manures, spraying, pruning, etc. But they do give a good comparison of the value of the crop as affected by the potash treatment. In order to simplify the Table, the figures for tipped and untipped trees are here averaged, and are taken in single year instead of two year periods.

It is quite easy to prepare a Table of this kind, and to ensure that the figures fairly represent the actual results. But it is by no means easy to indicate how much we have actually gained by our potash manuring. It is impossible to say how the trees on Plot "P" would have compared with those on Plot "C," from 1923 onwards, had the former not received any applications of potash. In the great majority of cases, as shown above, the trees on Plot "P" were, up to the time of the first application of potash, falling further and further behind those on Plot "C."

Presumably this process would have continued to some extent, even if not at the same relative rate. As a matter of fact, in a number of cases it did continue, even after the first application of potash; but it is impossible to say whether this is solely due to the bad condition of the trees, following from their more severe leaf scorch, or partly to an influence of the potash, tending, as suggested above, to throw the trees out of bearing. But there is no reason to suppose that the trees on Plot "P" would, without potash treatment, have relatively improved to any considerable extent from the point they reached in 1922.

Table VI.

Crop in Bushels per Acre, and gross Value, as affected by Potash Treatment.

	1922.		1923.		1924.		1925.		1926.		1927.	
	Crop.		Crop.		Crop.		Crop.		Crop.		Crop.	
		£ s.		£ s.		£ s.		£ s.		£ s.		£ s.
Lane's Prince Albert:												
Control "C"	47½	7 4	119	17 11	169	38 9	332	41 7	201	57 13	430	25 19
Treated "P" ..	36	5 4	62	9 5	129	31 12	400	53 0	220	66 3	585	52 7
Loss or Gain on basis of 1922	**—11½**	**—2 0**	**—28**	**—3 8**	**+1**	**+3 15**	**+148**	**+23 3**	**+68**	**+24 10**	**+259**	**+33 12**
Lord Derby:												
Control "C"	65	11 4	105	17 7	128	35 0	175	18 1	221	50 1	156	14 6
Treated "P"	46	8 2	63	11 2	114	31 10	134	15 18	367	98 2	269	38 16
Loss or Gain on basis of 1922	**—19**	**—3 2**	**—11**	**—1 9**	**+23**	**+6 7**	**+10**	**+2 17**	**+211**	**+61 18**	**+159**	**+28 9**
Rival:												
Control "C"	19	3 19	36	5 2	52	7 10	164	50 18	105	55 14	110	36 16
Treated "P"	19	3 4	16	2 13	50	7 4	250	82 2	142	76 4	297	122 3
Loss or Gain on basis of 1922	**0**	**—0 15**	**—20**	**—1 10**	**—2**	**+1 3**	**+86**	**+34 6**	**+37**	**+31 2**	**+187**	**+92 7**
Cost of Potash	None.		£1 10		None.		£2 8		£2 8		£2 8	

If, then, we take the crop of 1922 as indicating what would have been the relative cropping of Plot " P " in subsequent years, had no potash been applied to it, we are not likely to be exaggerating the improvement in returns brought about by the potash treatment. In 1922, although in the case of Rival the two plots cropped about equally, the cash return from all three varieties was lower on Plot " P." (In the case of Rival this is, of course, due to the fact that the fruit on Plot " P " was smaller.) The figures for " Loss or Gain " show how the actual figures for Plot " P " compare with those that would have been obtained, had the crop and value from the two plots continued in the same proportion as in 1922. For example, the Table shows that in 1927 there was a gain on the variety Lane's Prince Albert on Plot " P " of £33 12s. per acre. This indicates that, had the potash not been applied, and had Plot " P " cropped in 1927 in the same proportion to Plot " C " as in 1922, the value of its crop would have been, not £52 7s., but £18 15s. The figures given at the bottom of the Table showing " Cost of potash " are based on Sulphate of Potash at £12 per ton, probably slightly above the average price during the period.

We find, then, that even had the trees on Plot " P " not deteriorated any further, relatively, than the point they had reached in 1922, even as early as 1924 we were obtaining slightly more return from each of the three varieties than we should have done without the potash treatment. This improvement increases, until in 1927 the return varied from nearly three times to nearly four times as much as we could have expected, had we not applied potash.

There are, of course, certain increased expenses to set against this higher return. The heavier crop involves a heavier cost for picking, packing and hauling to the station, though this increase is in smaller proportion than that shown in number of " bushels per acre," because the fruit from Plot " P " is now larger than from Plot " C " and consequently quicker to pick and grade. There is also the very small labour cost of applying the sulphate of potash, which at most cannot be more than 2s. or 3s. per acre.

Finally, there is the extra labour cost of pruning, caused by the more vigorous growth of the trees on Plot " P." In the case of the leader tipped trees this may be a material item, at least with such varieties as Allington and Grenadier, which make large numbers of lateral growths. In the winter 1926-27 a record was kept in certain cases of the length of time required to carry out the pruning. It was found that the trees of the varieties named took from 30 per cent. to 70 per cent. longer to prune on Plot " P " than " Plot " C." In the case of such varieties this would be a serious item ; but with others, like Gladstone, Lord Derby, and Newton Wonder, and with trees not regularly leader tipped, it would usually be negligible.

Against these increased expenses on Plot " P," we can reckon the very much higher present value of the trees. Even if we had no record of the performance

of these trees during the last three years, we could claim for them a definitely higher potential value, owing to their greater vigour and comparative freedom from leaf scorch in the summer. Actually there is every reason to think that, if the different treatments of Plots " C " and " P " as regards potash manuring were maintained in the future, the differences shown in Table VI. would increase rather than diminish.

Though it would be difficult to estimate the sum involved in these additional expenses on Plot " P," and the countervailing higher value of the trees, it can be said with confidence that they could not materially affect the larger differences shown in Table VI. It is, in fact, clear that in some cases these differences amount to much more than the difference between profit and loss. Take, for instance, the case of Lord Derby in 1927. The figures show that, had no potash been applied to Plot " P," in all probability the gross value of the crop would have been little over £10 per acre (it was only £14 6s. on Plot " C "). Actually the gross value was £38 16s. Any grower will recognise that such a gross return of £10 per acre would inevitably involve a heavy loss, whereas £38 16s. might leave a moderate profit, at least in a year which did not involve heavy costs for spraying.

It must be remembered, of course, that these three examples give a more favourable result than would the average for all our varieties. The five apparent exceptions to the rule, dealt with above, undoubtedly still show a loss from the application of potash, in spite of the generally increased size of the fruit ; whilst in most other cases the gain is less than the larger gains shown in Table VI. But there cannot be the slightest doubt that the whole plot, even including varieties like Bismarck, Norfolk Beauty and Cox's Orange, which have had frequent years of very light crop, shows a gain from the application of potash far more than enough to cover the extra costs involved.

In regard to the cost of the four applications of potash so far given, shown at the bottom of Table VI., it must be emphasised that we do not know how far the later applications were necessary. Results obtained in commercial plantations certainly suggest that one application of potash, even if heavy, is not enough by itself to cure a severe attack of leaf scorch. But it is quite possible that our first two applications might have produced almost, if not quite, as much result as we have so far obtained, without those of 1926 and 1927. We have no means of determining from this trial how far these later applications were justified.

The probability pointed out above that potash manuring may in some cases temporarily reduce or delay cropping raises an interesting problem in commercial practice. If leaf scorch hastens the cropping of young trees, how far would a grower be justified in withholding potash, in order to secure earlier crops ? The best practice must, of course, depend on circumstances. With trees

on the varieties of root-stock associated with leaf scorch (Doucin No. II., Improved Doucin No. V., and the nameless No. VII.) and planted in soil where leaf scorch is likely to occur, it would be at best very risky to try to get earlier crops in this way. Given a series of seasons in which leaf scorch was not severe, it is possible that the grower might thus increase his early returns quite materially. But if a year of severe leaf scorch, like 1924 and 1927, supervened, he would probably lose very much more than he gained; the leaf scorch might suddenly become so severe that the crop would be actually reduced instead of being increased, and much of the fruit would be so small as to be almost unsaleable. In any case, even a moderate attack of leaf scorch is bound to lower the potential value of the trees by reducing their cropping capacity in later years. It would undoubtedly be preferable, wherever possible, to hasten cropping by less severe pruning, rather than by letting leaf scorch take its course.

In conclusion, the writer would like to express his thanks to the many members of the Recording Staff, without whose willing co-operation the data on which this paper is based could never have been collected. And he would like particularly to thank Mr. T. N. Hoblyn, for much help in preparing the data, and for his examination of the records of time of picking, dealt with in Section 13.

SUMMARY.

The application of sulphate of potash to part of the "Pruning Plot" at East Malling has yielded very definite results. In comparison with the untreated trees, with a very few apparent exceptions, those which have received potash have shown :—

(1) Very much less "leaf scorch."

(2) Greatly improved cropping, in both quantity and size of fruit.

(3) Greatly increased growth, as indicated by increase in girth of stem, weight of prunings, and number of shoots.

Both (2) and (3) apply to Worcester Pearmain, which is resistant to "leaf scorch," as well as to other varieties.

(4) A probable tendency, in certain exceptional cases, towards temporarily reduced cropping as a result of the greater vigour of the tree.

(5) A probable tendency in some cases towards a heavier "set" of fruit.

(6) No consistent tendency towards more highly coloured fruit. Most of the "leader tipped" trees showed the reverse tendency, probably owing to the shading effect of the denser foliage where potash was applied.

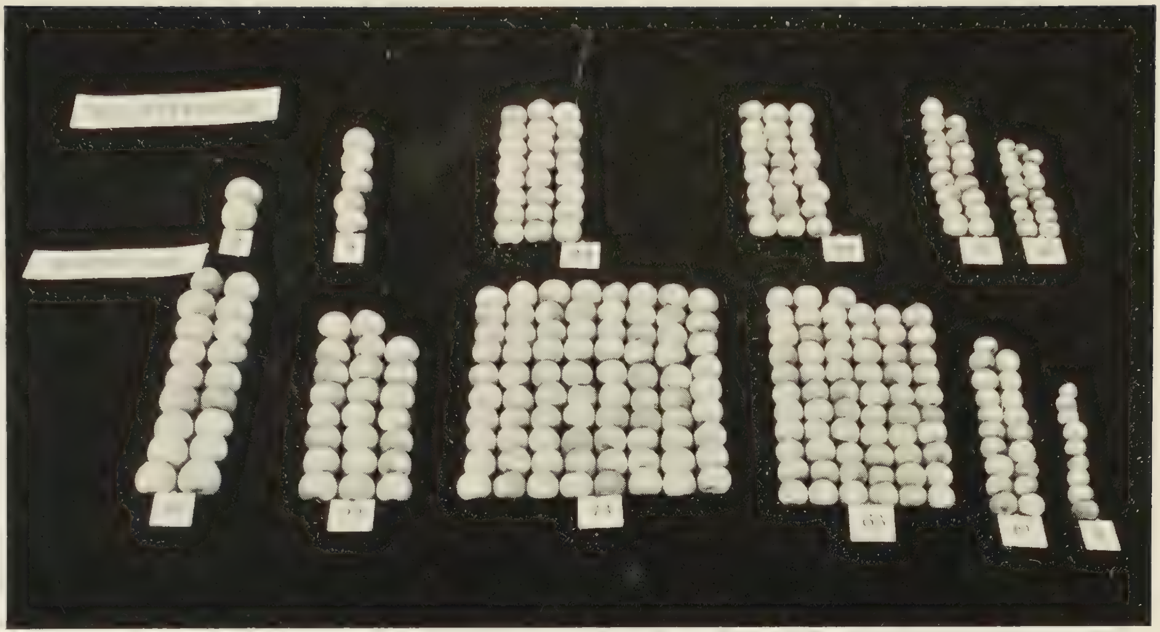
PLATE V

GRENADIER.

Specimens of Foliage, 1927.

Right, Plot "C." Control.
Left, Plot "P." Receiving Potash.

PLATE VI.

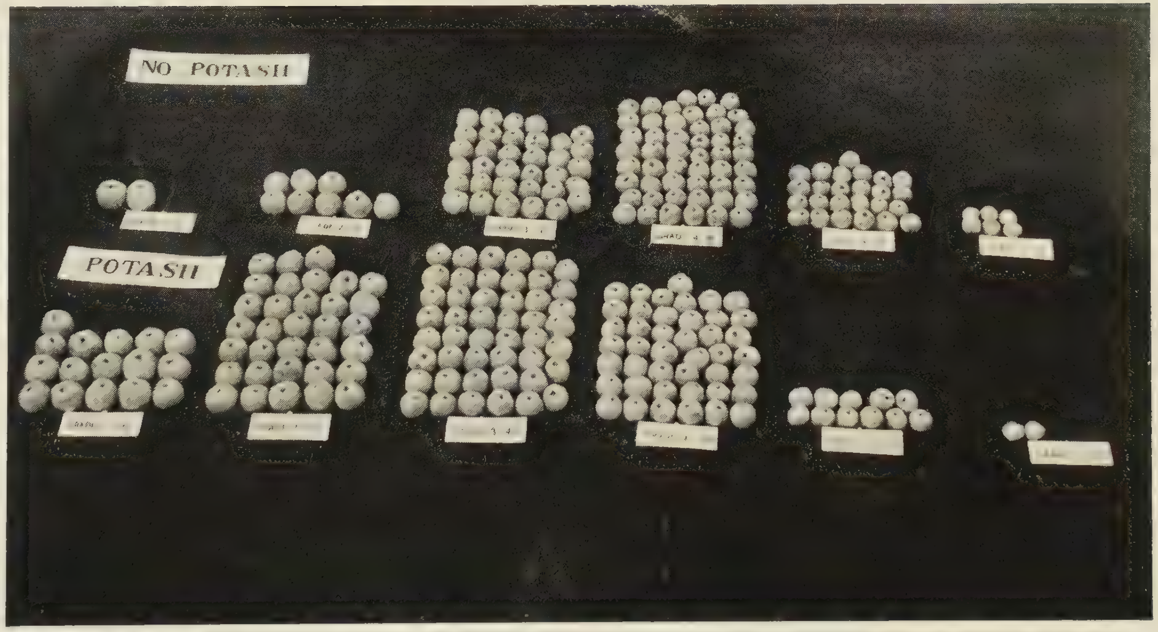


RIVAL.

Average Crop per Tree (Tipped), 1927, in size grades.

Above, Plot " C." Control.
Below, Plot " P." Receiving Potash.

PLATE VII.



Lord Derby.

Average Crop per Tree (Tipped), 1927, in size grades.

Above, Plot "C." Control.
Below, Plot "P." Receiving Potash.

(7) An apparent tendency, after the first application of potash, towards earlier maturity of fruit. In most cases this tendency did not persist.

(8) Greatly improved financial returns.

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EXPLANATION OF GRAPHS.

The Graphs show the Relationship (in biennial periods), between Plots " C." (Control) and " P " (Treated) before and after the first application of Potash to Plot " P " (1923)

Figures for Plot " C " (Control) taken as 100 (heavy horizontal line).

Continuousline ——— = Untipped Trees.

Broken line – – – – = Tipped Trees.

Heavy vertical line shows first biennial period including an application of Potash.

For explanation of significance of curves, see text.

(*Received* 27/1/28.)

HOW THE RIBBON-LIKE SCARS ON APPLES ARE MADE BY THE APPLE SAWFLY

(*Hoplocampa Testudinea* Klug).

By F. R. PETHERBRIDGE, M.A.
School of Agriculture, Cambridge.

In addition to the serious damage which the apple sawfly larva causes by eating out large cavities in the interior of the fruit it also causes the peculiar ribbon-like scars formed on the surface of the apple. These have in the past been attributed by some authors to caterpillars and by others to the apple sawfly larvæ in their efforts to bite a way through the skin.

This damage has also been confused with that caused by the apple capsid bug, *Plesiocoris rugicollis*.

The following observations show that the scars are the results of tunnellings underneath the skin by the young sawfly larvæ followed by the breaking down of the skin over these tunnels and the subsequent growth of the apple.

My attention was first drawn to the way in which this damage is caused by Mr. F. Howe, of Wellingborough, who made the following observations in May, 1924.

Fruit Examined.

Apple No. 1.—Found a burrow (or tunnel) *just under skin of* Apple of about three-quarters of complete circle of apple, then the burrow led to the interior of fruit, where the maggot was feeding near the core.

Apple No. 2.—Apple almost complete encircled with tunnel (immediately under skin) with hole through skin at each end of tunnel. *At no place along the tunnel was the flesh eaten deeper than immediately under the skin.* No maggot found in this specimen. The hole where the maggot had apparently entered was choked up with frass, but the hole by which it had left the fruit was quite clear for a short distance.

Apple No. 3.—Tunnel circled almost twice round apple and not eaten deeper than tunnel immediately under the skin. This apple was more fully developed, and at the end of the tunnel on the side of the apple, where the fruit had swollen most, the skin above the tunnel had cracked and crumbled, exposing the " flesh " of the apple. The part of the tunnel that had opened out (probably burst open by the side of the apple swelling in growth) was " rusted " over and now almost level with proper skin of apple, and had practically the same appearance as the rust " trails " and " circles."

Apple No. 4.—Tunnel under skin almost three-quarters round apple; four holes through skin into the tunnel, two of which holes led to one main burrow to bottom side of fruit *core*, but no maggot present.

Apple No. 5.—Tunnel under skin, considerable and irregular with burrow into core of apple, containing maggot of Sawfly, as previously described.

Apple No. 6.—Tunnel one and a quarter round fruit, three holes in tunnel; but no maggot found. Another hole, in same fruit, leading from stem to depth of nearly half inch, but no maggot found.

Examined numerous other apples, and found, in each case of affected fruit, similar results to the fruits first examined and noted above.

At a later date examined affected and growing apples on the trees and found many specimens where skin over tunnel had broken apart—partly through dryness and " crumbling " of skin above tunnel, and partly through the swelling of the growing apple—leaving the tunnel exposed and with ragged edges of apple skin along the edges of exposed tunnel.

Later on found " bottom " of tunnel had grown " flush " (level) with proper skin of apple, and the previous ragged edges had disappeared, except in a few cases.

Still later found that where the tunnel had been, the " rusted " surface had swelled to slightly above the level of proper skin, probably owing to there being now no true skin to prevent pressure (withhold pressure) of cell-growth of " flush " of apple.

I received the above notes from Mr. Howe in December, 1925, and in 1926 I made some observations on some Worcester Pearmains (which appear to suffer more from sawfly attacks than other varieties) and towards the end of May found a number of apples tunnelled underneath the skin and with the sawfly larva present in the tunnel in most cases. Later on a large percentage of these tunnelled apples fell from the trees. Of those which remained I first noticed the breaking down of the skin over the tunnels on June 8th, and later on these tunnels developed into the characteristic sawfly scars.

In 1927 I made some further observations on Worcester Pearmain and some seedlings. On May 15th I labelled a number of apples which showed tunnels and periodically examined some of them. At this stage the larvæ were rather more than 2 mm. long. Many of the tunnels ran from near the calyx to the equator and of these some had a single small hole at the top of the tunnel with the larva present facing the stem end. In others the tunnel had a hole at each end and others also one or two additional holes between these.

Occasional tunnellings were found round the top of the young fruit in the base of the sepals, and sometimes the larva had burrowed through the calyx into the calyx cup.

In some apples in addition to the tunnels the larvæ had bored their way into or towards the core of the apple. Most of the tunnellings were immediately under the skin but in several cases they had gone rather deeper into the flesh of the apple. In all these cases the larvæ were sometimes present and sometimes absent. The tunnellings were full of frass.

Later on a large percentage of the tunnelled apples fell from the trees, but of those remaining the tunnels began to break down on June 5th (Fig. 1 shows the tunnelling on young apples at this date and it will be noticed some of the tunnels were still intact whereas in others the skin had broken).

As the apples grew the skin over the tunnels broke leaving furrows along the surface of the apple. In some apples the furrows were not complete but were joined by small tunnels. These are probably the cases where the larvæ bore deeper into the flesh of the apple and not immediately under the skin. As the apple grows the furrows become shallower and eventually a corky scar more or less on a level with the skin of the apple remains.

Figs. 2 and 3A both illustrate cases where the tunnel has not completely broken down and in these cases where the scar is not continuous the scars are joined together by unbroken tunnels.

Sawfly scars should not be confused with capsid scars as the latter are usually much more irregular (see Fig. 3B) and even where the former somewhat resemble the latter the methods by which the scars are caused and the occasional small tunnels joining the scars are very helpful in diagnosis. The sawfly scars usually start near the calyx as the eggs are laid there.

(*Received* 10/2/28.)

FIG. 1.

Young apples with tunnels made by the Apple Sawfly larvæ. (Photographed June 5th, 1926.)

FIG. 2.
Characteristic Ribbon-like scars caused by the breaking down of the tunnel made by the apple sawfly larvæ. In one of the scars a portion of the tunnel is unbroken.

(A) (B)

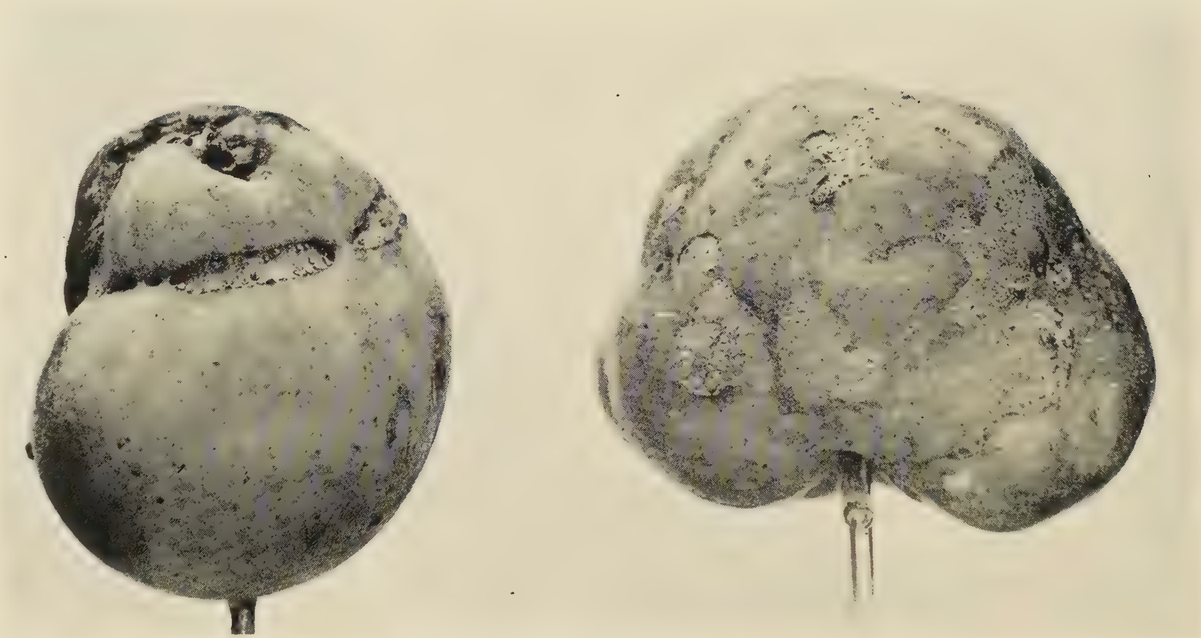

FIG. 3.

(A) Scars caused by the partial breaking down of the tunnel made by the Apple Sawfly larva. Portions of the tunnel which have remained intact can be seen.

(B) Scars caused by the apple capsid bug *Plesiocoris rugicollis*.

PLUM ROOTSTOCKS; THEIR VARIETIES, PROPAGATION, AND INFLUENCE UPON CULTIVATED VARIETIES WORKED THEREON.

By R. G. HATTON, J. AMOS and A. W. WITT,

With Appendix by T. N. Hoblyn.

East Malling Research Station, Kent.

It is now fourteen years since the writers initiated investigations upon rootstocks for plums, with a view to gaining more precise knowledge as to their nature, use, influence and suitability.

The behaviour of Victoria Plum trees raised on the Research Station upon a representative collection of rootstocks, planted upon three different soils , for eight seasons, has now been recorded. There have also been under observation for seven seasons a representative collection of plum varieties (embracing *Domestica*, *Cerasifera* and *Insititia* species), upon a similar range of rootstocks.

Two other sources of information are at the disposal of the writers to assist them in drawing deductions. There is the history of the behaviour of the young trees year by year over eight seasons in the Nursery at East Malling. There are the very valuable observations which it has been possible to make upon mature trees in growers' plantations, where, after an identification of the rootstock from the suckers thrown up from the roots, it has been possible to confirm or modify the deductions which have been drawn from the behaviour of the experimental trees grown under more controlled conditions.

The propagation experiments have now been carried out for a sufficiently long period to make it possible to report on the suitability of various rootstocks for different varieties from the tree raiser's point of view, with some confidence. The eight years' growth of the oldest experimental trees, checked by younger series, and by observation in established orchards, affords reliable data as to the effect of different rootstocks upon the vigour and habit of growth, the roothold of the tree and the propensity of the rootstock to sucker.

With regard to the influence of rootstock upon cropping, although the experimental trees are still very young and have borne only light crops, it is possible to present some data with regard to the influence of rootstock upon the time and habit of blossoming, and also some early indications as to effect on actual crop.

Field experiments can only unfold their results slowly as each season passes, and now and again individual seasons are apt to make results appear contradictory.

No one appreciates this fact more than the grower himself, hence he should be sufficiently schooled to read this report in the right frame of mind, and to compare its indications with those of his own horticultural experience. Fellow investigators may find it useful to be in possession of some of the data emphasising problems, such as a definite incompatibility of stock and scion, which have so far not been apparent in the investigations with apples.

The Rootstocks in Commercial Use.

It is not the intention here to describe in detail the various plum stocks in common circulation. Descriptions of most of the principal varieties were published in 1921 (1), and if growers become interested enough to try and identify the rootstocks upon which their own trees are worked, they can refer to that fully illustrated Bulletin.

It may be necessary, as new selections become adopted by nurserymen, to add to these botanical descriptions, though, since the initial descriptions were published, only one additional rootstock seems to have come into fairly wide commercial circulation, namely—St. Julien de Toulouse.

Meanwhile it is sufficient to point out that the rootstocks in present use in this country—and apparently Western Europe—are of at least three species of Prunus.

Such stocks as the Brussel, Broadleaved Shining Mussel and the Pershore would almost certainly be grouped as Prunus domestica ; the Cluster Damson, the Common Mussel, and some St. Juliens, as Prunus insititia ; and the Myrobolan Stocks as Prunus cerasifera.

If the Mariana may be considered to be Prunus munsoniana, then a fourth species can be added.

Unfortunately this question of rootstocks for Plums is still further complicated by the many varieties of the above-named species that have come into use, and by the fact that some are raised from seed and display almost infinite variety. In addition to those rootstocks especially raised for the purposes of budding and grafting, such as the Brussel, Brompton, Common Plum, Mussels, Myrobolans, St. Juliens, Black Damas, and Mariana, local usage has brought into circulation, through the sale of plum suckers grubbed from certain cultivated varieties growing upon their own roots, a number of less widely known sorts such as the Pershore (Worcester), Blaisdon (Gloucester), Gage (Cambs), Bush (Kent), Cluster (Kent), Drooper (Warwick), Magnum (Warwick) and Bastard Orleans (Hants).

Thus the investigator is faced with an almost endless series of possible combinations of stock and scion, about the suitability of any one of which he is liable to be asked. Unfortunately, results to date give no clear indications that, even if all these varieties could be grouped under their proper species, any great

advance towards a more precise knowledge of their particular suitabilities would be made, because everything points in the case of Plums to very fine degrees of varietal preferences. It is not possible to say that one species of rootstock suits a particular group of plums, and another species another. On the other hand, there is one generalisation that can perhaps be made with some safety, namely, that most of the P. Cerasifera stocks tend to invigorate varieties worked thereon, whilst the P. Insititia stocks generally act in the reverse direction.

Identification of Stocks.

It has already been stated that these varieties of rootstock are capable of botanical identification, and that descriptions of those in most common use have already been published. When grown under normal conditions, the summer foliage characters are sufficiently constant upon the current year's growth to make them readily distinguishable, whilst the early bud breaking and shoot colour of the different varieties in spring are a useful adjunct in roguing operations. Suckers grown under very shaded conditions are often difficult to identify until they have been grown in open ground. The very wide use of such stocks as seedling St. Juliens, which, as imported into this country from the continent, show nothing approaching the similarity which Professor Hedrick claims for them in America (2), makes much identification in commercial plantations very speculative. Finally, whilst the main species can be fairly easily recognised in winter from wood and bud characters, varieties of the same species are not easy to recognise, though their general habit of growth often affords some clue.

Reasons for the Use of Rootstocks for Plums.

For conditions in this country at any rate, it is impossible to subscribe to Hedrick's dictum that "The cultivated fruit tree is a two part plant (i.e., stock and scion) because in no other way can varieties be propagated true to name," because there is ample evidence that many of those common varieties of Plum, already enumerated, are grown on their own roots and are perpetuated by suckers. Trees of a number of the better known varieties, such as Victoria, Czar, Early Rivers and Purple Egg, have now also been established upon their own roots, by layering methods.

Finally, varieties of plum are occasionally so free rooting as to exhibit the typical Root-knots, or root initials, on their branches, which betoken the possibility of raising them from cuttings.

However, most cultivated varieties do not propagate readily by these simple vegetative means, and many of those that are thus propagated develop slowly, at least in the early years. Hence, if certain desirable rootstocks could be readily propagated, and cultivated varieties worked thereon, time and expense is undoubtedly saved, and, probably, quicker maturity is ensured.

The use of plum stocks has probably become very general purely as a matter of convenience rather than from absolute necessity.

Whether plum trees worked upon such foreign rootstocks can ultimately improve upon the vigour, cropping, health, longevity, etc., of the same variety grown upon its own roots remains to be seen when the comparative sets of trees at East Malling mature. In the early years at any rate our results are somewhat contradictory (3). It is certain that unless some very good reason can be brought forward for raising most commercial varieties upon their own roots, they will continue to be budded and grafted. It is then worth while to go further into the question of these rootstocks and their desirability, especially as proof is now forthcoming that a considerable measure of control can be attained over the worked tree by rootstock selection.

Desirable Qualities as a Guide to the Choice of Stocks.

From the tree raiser's point of view there are several immediate necessities: First, that the stocks he uses should be readily obtainable or, in other words, readily propagated. He cannot be expected to use scarce stocks unless growers are prepared to pay him an enhanced price for the resulting trees. Secondly, the stocks must allow of a good and consistent "take of buds" in the Nursery. Thirdly, they must produce a high percentage of saleable trees of good appearance. Finally, the nurseryman wants to give lasting satisfaction in the ultimate behaviour of the trees he sends out. In this last connection it must be remembered that only the test of time, after the trees have been in the orchard five or six years at least, will prove whether the combination has been a good one.

The fruit grower should be most exercised in his mind about this ultimate performance rather than about immediate appearance. He wants a tree sufficiently large to carry considerable crops, sufficiently long lived to fulfil that promise, and sufficiently quick and certain in bearing to ensure early, and, if possible, regular returns. It is very doubtful, however, whether growers, generally, realised that rootstocks might influence these matters. Consequently they gave no definite lead by asking for trees worked upon particular stocks.

As a result, apart from the observations of a few expert plum growers such as those of Mr. W. T. Afford of Bluntisham, Hunts, which were reported upon by Mr. F. R. Petherbridge (4), very little accurate information has been accumulated until recently upon these points. Since local variations of soil and treatment may make all the difference, it is essential that growers should supplement our observations in order that our knowledge may be anything like exhaustive.

Sources of Supply and Methods of Propagation.

The varieties of Plum Stock in present use are obtained by various methods. For clarity, they may be grouped as follows:—

(*a*) *Seedlings.*

The great majority of the Myrobolan, St. Julien and Black Damas Stocks are raised on the Continent from seed, a comparatively cheap method. The many collections of chance seedlings that the writers have inspected bear out the suspicion that these stocks are very variable. From amongst the St. Juliens and Black Damas Seedlings they have, on several occasions, picked out a range of stocks which would botanically pass for different species, and which horticulturally illustrate admirably extremes in degree of suitability. Even the Myrobolans have exhibited greater variation than was expected, both botanically and horticulturally. The best that can be said of these seedling stocks is that usually the greater proportion make creditable trees, but that, whilst their use continues, trees will not reach either in the Nursery or in the Orchard a high standard of uniformity and attainment. On the other hand, it must be fully realised that whilst the supply of the reasonably good plum stocks, vegetatively raised, is so much in default of the demand, the use of these seedlings is bound to continue.

(*b*) *Vegetatively Raised Stocks.*

The methods employed in reproducing plum stocks true to the parent type by vegetative propagation may be described under four headings :—

(i) *Layering.*—Certain of the common types of Plum stock such as the Brussel and Common Plum are raised very readily in Western Europe by various forms of mound layering, the annual growths being earthed up and sending out fresh root initials into the soil drawn over them. This ready rooting probably accounts in no small degree for the popularity and wide distribution of these two stocks.

Varieties of Myrobolan and St. Julien, such as Myrobolan Blanc and St. Julien de Toulouse, are also raised in the same way very readily on the Continent.

Many other varieties of plum stock, such as the various Mussels and the Brompton, can be and are, to some extent, raised by this method. But under most conditions they root much less freely, and another method is more commonly employed. Some rootstocks such as the Pershore seem extremely difficult, under many conditions, to multiply by layering or by any artificial method of vegetative reproduction. That it is possible to select other desirable root-stocks, possessing the characteristic of ready layering, has been demonstrated by the selected Myrobolans, St. Juliens and Damas, tested at East Malling.

(ii) *Root Cuttings.*—Owing to the comparative difficulty referred to above of layering the Mussel stock varieties, the method of reproducing them from root cuttings has been extensively employed. When young nursery trees are lifted and root pruned before replanting, these prunings are saved and, in a propitious season, give a good proportion of workable stocks in the ensuing year. But the

scarcity of the Mussel Stocks testifies to the fact that this method is none too sure. The Pershore again, on the other hand, grows but shyly from root cuttings.

(iii) *Wood Cuttings.*—There are a few varieties of plum stock in commercial circulation which are sufficiently ready rooting to be raised from ordinary hard wood cuttings. Principal among them is the Mariana. Varieties of Myrobolan can be and have been selected which will root readily in this way, and, recently, from among the Black Damas Seedlings, the writers have selected a variety which roots readily by this method, though most varieties of Domestica and Insititia stocks could only under special conditions be so raised commercially. The method of using soft wood cuttings has apparently never been employed commercially in the raising of plum stocks, but the fact that it is proving an effective method of quickly and surely reproducing certain varieties has been reported already (5), and the possibilities of applying such a method commercially are being considered.

(iv) *Suckers.*—Another source of rootstock supply is the established plantation. The suckers thrown up from the roots of fruiting trees are frequently grubbed up after leaf-fall and sold by the thousand as stocks. There are several disadvantages to this source of supply. Unfortunately, it is often, though not universally, the less desirable stocks, such as Brussel, that sucker badly, whilst a sought-after variety like Pershore does not generally produce prolific suckers. Then the normal cultivations in the plantation frequently damage these suckers, and if they escape Silver Leaf, they are at the best damaged specimens. Many varieties, like the Pershore, do not root freely even thus, and, by the time they are fit to be dug up, they have become over coarse for making the best stocks. Finally, great care is required in selecting and marking such suckers whilst they are yet in leaf, otherwise this source of supply is almost certain to afford a considerable admixture of good and bad varieties. Indeed the writers have not infrequently witnessed the most costly mistakes resulting from the budding of suckers wrongly identified.

It is not intended here to go into the details of these propagation methods, or of the new methods and selections that are being tried, but this summary is given to indicate the present limits and sources of supply, which must at the moment to a great extent govern our practical choice.

The "take" of Buds—the so-called "Incompatibility" Problem.

Really even more important than supply is the question of the suitability of the stock for its purpose, that of receiving the bud and graft. Now for many reasons, including that of economy, preference has generally been shown by tree raisers for budding rather than grafting stone fruits. The failure of buds to "take" has frequently been attributed to seasonal conditions, and the failure of buds to grow out more than a few inches to possible fungus or insect attacks.

It is probable that all these explanations have at one time or another been a cause of the failure of buds, but the co-ordinated series of investigations in the Research Station's Nursery has shown that this failure may, year after year, be associated with certain rootstocks and certain scions, and that certain combinations invariably give poor results. Whilst the writers are fully aware that seasonal fluctuations, and the actual condition of the stock and bud at the time of manipulation do modify the results, yet they have overwhelming evidence to-day that there exists a definite lack of suitability between certain combinations ; an "incompatibility" which manifests itself more or less markedly whatever the ameliorating conditions.

Experience, for instance, has taught us that to get the best success with budding Brussel stock with any varieties, that stock must be budded early, as it is very apt to dry out. On the other hand, there is evidence that the frequent failure of the buds of a variety like Jefferson's Gage to "take" is due to the peculiar development of the node and consequent manipulative defects. Again, it has been found that if the raiser substitutes grafting for budding, he will largely get over the initial difficulty of getting a tree.

Yet there is strong evidence of the fact that, whatever the condition of the bud or stock at the time of manipulation, certain combinations such as Czar on Brussel, Common Plum or St. Julien de Toulouse stock will exhibit a comparative failure, and demonstrate this lack of suitability. The phenomenon is even more striking in the case of peaches.

Now the "incompatibility" may take several forms according to the combination made or the ameliorating effects of season. Buds, though apparently alive, may never grow out at all ; they may grow out a few inches unhealthily and stop, or they may die outright. They may even give a comparatively vigorous maiden tree which, at the slightest application of pressure, breaks out at the union. Some of such trees may even withstand this test and may live for several years making little fresh growth until they come to a standstill and ultimately die. (See Figure 4.)

In this paper, it is not proposed to enter into the full details of these nursery experiences. It must suffice to say that this phenomenon exists, and is of sufficient importance to serve as a warning to tree raisers and growers. Until the principles upon which right and wrong selection should be based have been fully worked out, it is impossible to advise accurately upon every possible combination of stock and scion.

On the other hand, it is possible to indicate certain lines of safety, and certain danger points.

The Brussel, Common Plum and St. Julien de Toulouse (or Prunus Damas of some nurseries) stocks very frequently give disappointing results due to incompatibility. The East Malling selections from commercial St. Julien and Myro-

bolan seedlings have gone to prove that a percentage of even these will not readily take the bud. On the other hand, the Pershore, the Common Mussel, the Brompton and good selected Myrobolan stocks will give a very wide degree of satisfaction in the nursery—so will good selected and vegetatively raised St. Julien and Damas. Most plum varieties also appear to " take " well on Mariana.

From the standpoint of scion selection, it is also possible to give a warning, for, whilst plums such as Victoria and Pershore will make some sort of a tree on almost any stock, varieties such as Czar, Pond's Seedling, most Damsons and Peaches, exhibit very striking preferences.

A fairly wide series of combinations of commercial varieties upon commercial rootstocks have been tested out, and in due course it is hoped by these empirical methods to discover further " incompatibilities " and special partialities.

The Table given below, illustrates very well the type of result which is being obtained.

TABLE I.

Percentage of Czar Buds " taking " on various rootstocks.

	1919.	1921.	1922.	1923.	1924.	1925.	1926.
Myrobolan	90	80	90	90	91	90	96
Brompton	90	none budded	80	89	70	89	76
Brussel	14	9	0	69*	31	20	25
Common	19	75†	25	81†	30	20	38

* There were many subsequent losses from breakage.

† These develop into small undersized trees, generally surviving only for a few years.

Speaking quite generally, in the full knowledge that there are here and there exceptions, it can be stated that by far the most attractive looking trees in the nursery have been raised on Myrobolan, Pershore, Brompton, Common Mussel and Mariana stocks, together with certain selected Damas and Myrobolans.

It remains to be seen how far these stocks appear to be answering the third test, that of giving ultimate satisfaction to the grower in their performance.

THE BEHAVIOUR OF CULTIVATED PLUMS UPON DIFFERENT VARIETIES OF ROOTSTOCK.

American Experiments.

With the exception of two series of trials carried out by Professor Waugh, at Vermont and Massachusetts, and Professor U. P. Hedrick at New York, there was no very definite evidence of the influence of Stock upon Plum varieties, though

pomological literature faithfully repeats a number of traditions. Professor Waugh's experiments, initiated in 1898, and reported upon in 1909 (6) dealt with varieties worked upon seedlings of the following species of Prunus—Americana, Wayland, Mariana, and Peach—little used as stocks in this country, and the records, though extremely interesting from a scientific point of view, demonstrated principally differences of botanical influence, and were not, at the time of the report, carried on into the fruiting stage.

Dr. Waugh concluded that the Mariana stock in particular seems to produce the most obvious changes in the growth of plums worked upon it. These changes he summarised as follows :—

1. Broader leaves.
2. Finer marginal serrations.
3. Greater annual growth.
4. Larger internodes.
5. Greater diameter of branches.
6. Greater variability in all characters.

Professor Hedrick's experiments, also carried out over ten seasons, and reported on in 1923 (2) did include trials of at least two varieties of rootstock, Myrobolan and St. Julien, commonly used in Europe. Unfortunately the very great variability of these European Seedlings, which is so typical of these groups, was explained as "accidental," so that it is extremely difficult to translate his deductions into terms of European conditions. For instance, the East Malling trees on *Seedling* St. Juliens show every variation from restricted quick cropping trees to very vigorous ones slow to blossom, and it is only by having very considerable units of such trees under observation that it would appear safe to draw any deductions at all. Moreover it has been proved that, by the selection and vegetative reproduction of these St. Juliens, these variations, far from being accidental, can be repeated at will. However, Professor Hedrick stated that, even with units of six trees, marked differences in vigour and productiveness, as gauged by diameters of trunks and by yield of fruit, were apparent as a result of stock influence. Myrobolan was best, as regards vigour and productiveness, for Bradshaw, Grand Duke, Italian Prune, Lombard and Reine Claude, the Domestica sorts and the Insititias. Native plums grew best on Mariana, and Japanese varieties grew equally well on Myrobolan and Peach, though exceptions to such general rules were reported.

PLAN OF EAST MALLING EXPERIMENTS AND ITS EXECUTION.

(a) *Range of Stock and Scion species and varieties.*

A review of the plum stock market, very early on in these experiments, indicated that the stocks in most general commercial use were undoubtedly

Brussel, Common Mussel, Common Plum, Seedling Myrobolans, Seedling St. Juliens, with, to a lesser extent, Pershore and Brompton.

It was therefore decided that the preliminary trials should be carried out on these commercial stocks, and, for this purpose, a considerable quantity of each was bought in, and planted in nursery rows for identification and working. After these stocks had been left in the nursery for a couple of seasons, in order that they might be "rogued," they were finally worked, though, in the case of the Seedlings, a number of selections were made, representing the extremes of variation observed to recur in such collections. These selections of Myrobolan, St. Julien and Damas were kept for vegetative reproduction, and are included instead of seedling stocks in the later trials.

With this material to hand, the task first presented itself of trying to find out how far the particular species and varieties of rootstock would suit different species and varieties of plums, much on the same lines as the investigations of the American workers, though their experiments were then unknown to the writers.

As far as numbers of stocks available permitted, the aim was to work widely different types and species of European plums upon the whole series of stocks.

In the initial experiments, from "Domestica" plums, Victoria, Czar, and Pershore Egg were chosen as representing the widest range. These varieties were worked on all the seven rootstocks mentioned. Belle de Louvain, Giant Prune, and Purple Egg were also worked in smaller quantities on a curtailed series of stocks. Representing the Gage Plums, Denniston's Superb was worked on six varieties of stock.

Representing the Insititia Plums, the Common Black Bullace and Shropshire Prune Damson were worked on four and three varieties of stock respectively. Finally, the Cherry Plum (Myrobolan) was worked on five different stocks, to test stock combinations with Prunus Cerasifera scions.

In a later series of experiments Rivers Early Prolific and President were added to the list of plum scions, and Broad Leaved Shining Mussel and Mariana to the rootstocks. Still later, it was possible to include in the list of rootstocks many of the selected and vegetatively raised Damas, Juliens and Myrobolans.

A still wider range of plum varieties is being worked upon the complete series of stocks for "compatibility" tests.

(*b*) *Trials under Different Soil Conditions.*

Unfortunately, the quantity of rootstocks of certain varieties procurable, the phenomenon of "incompatibility," and the amount of land available, have always been limiting factors in making these trials completely exhaustive. So far the trials at East Malling extend over some ten acres of very even land at the Research Station, but the writers have been fortunate in being able to place and keep under some control, sets of trees on six other soils. In two of these

cases, at Heston, Middlesex, and at Tunstall, Kent, the trees are already old enough to yield some very valuable comparative results.

(*c*) *Unit of trees aimed at, and Successional Plantings.*

Rather than plant out, in a single season, a considerable unit of from twenty to thirty trees of each variety on each stock, it was decided to plant smaller units in successive seasons in the case of the principal varieties. Thus three successive plantings of Victorias, and three of Czars, and Purple Egg, have been possible. Hence, whilst, in any single plot or season, the experimental unit has been from six to twelve trees, planted in at least duplicate plots, the total unit aimed at has been from twenty to thirty trees planted successionally. The main object of this method has of course been to see how far seasonal effects influenced the general results, and to approximate to the frequent repetitions possible in experiments with annual crops.

The disadvantage of planting such small units annually is obvious from the point of view of statistical treatment of the records.

(*a*) *Disturbing Factors.*

Unfortunately several disturbing factors have in many cases lamentably reduced this unit still further, for, though both stocks and scions were carefully selected, very serious outbreaks of certain diseases have occurred successively in each plantation. "Silver Leaf" (*Stereum purpureum*) has entirely carried off some trees, checked the normal development of others, and forced the application of selective treatments on yet others. "Die-back" has, again, taken heavy toll especially of the Victorias and Czars (7), and this insidious disease is often hardly apparent before the tree entirely collapses. Finally, sometimes in company with the "die-back," and sometimes on its own account, the bark beetle (*Anisandrus dispar* Fab.) has attacked the stems of the Victorias. In a few instances, plum aphis (*Aphis pruni* Réamur) has crippled a tree, so that it must be discarded experimentally. As soon as effects of these troubles have become obvious, the attacked trees have been eliminated from the survey.

Despite all this, the accumulated evidence, from the surviving trees in the successive plantings, from trees of such a wide range of varieties, and from the considerable nursery data, appears sufficiently striking and consistent to justify the publication of the average results. The amount of variability from tree to tree in any one group is illustrated by the individual tree records given in Appendix A.

In an earlier progress report (8) some of the manifestations of stock influence were enumerated, but it is proposed here to deal with them in greater detail and to present further accumulated evidence. Though some data showing that rootstock does affect such botanical characters as leaf size has been collected,

attention has in the first instance been concentrated upon those features most likely directly or indirectly to influence their economic use.

Stock Influence on Vigour.

The first question that naturally arose was as to how far, if at all, the size of tree of any variety of plum could be controlled through the rootstock, since it was more or less a common belief that a dwarfing stock for plums had not been found.

Length of Wood Growth.

Whilst these experiments have shown that the extremes of vigour, which may be associated with the use of certain apple stocks, cannot be attributed to any of the plum stocks in common commercial use, yet differences of round about 50 per cent. in actual wood growth do exist. For instance, in the first series of Victoria Plums, upon which all the new growths have been measured annually, the trees worked on Myrobolan Seedlings made practically double the wood growth (13,171 cm.), of those on Brussel (6,873 cm.), during the first five years. The second series of Victoria trees showed those on Myrobolan Seedlings to have made a third more wood in four years than those on Brussel. The third series, which includes vegetatively raised Myrobolans, at three years, again shows difference of the same order.

The following Table gives the actual comparative average length of wood growth per tree made by each group of Victorias upon the series of stocks in these three plantings.

Table II.

Total Wood Growth in cm. of Victoria Plums on Various Stocks.

On Stock :	Unit.	1st Series planted. 1920.	Unit.	2nd Series planted. 1921.	Unit.	3rd Series planted. 1922.
		cm.		cm.		cm.
Myrobolan	(5)	13,171	(5)	3,253	(8)	5,134
Brompton		11,734		2,588	(9)	4,098
Pershore	(7)	11,566	(9)	2,912	(5)	3,272
St. Julien		8,738		2,606	—	—
Common	(5)	8,225	(8)	2,476	(5)	3,168
C. Mussel		7,257		—	(7)	3,674
Brussel	(5)	6,873	(9)	2,472	(6)	3,331

It is not claimed that all the differences shown above are by any means significant, but it is at least obvious that these stocks can be placed in two or three groups and described as Vigorous, Moderate and Dwarfing in respect of their influence upon the wood growth of Victorias.

Similar figures are given in Table III. showing the same approximate order of vigour when Czar, Purple Egg, Belle de Louvain, Denniston's Gage and Purple Egg are worked upon this series of rootstocks. With very few exceptions, which are generally more likely to be due to some inconstant unavoidable factor in manipulation or treatment, the same stocks produce vigorous trees or dwarfed trees of all the varieties experimented with. Thus, speaking generally, and allowing for possible exceptions resulting from "incompatibility," the Myrobolan Stocks, and the Brompton and, to a lesser extent, the Pershore, would be classed as vigorous. To this list, younger series of trees suggest that Mariana and Damas C, a new selection, ought to be added.

TABLE III.

Average Total Wood Growth Measurements in cms. of Plum Varieties on Different Rootstocks.

STOCK : Variety.	Czar.	Purple Egg.	Belle de Louvain.	Denniston's Gage.	Pershore Egg.
Myrobolan	6,012	—	5,848	7,873	4,403
Brompton	4,154	4,785	—	5,924	—
Pershore	4,806	4,627	4,888	5,927	4,603
Common Plum ..	2,859	—	4,451	5,105	3,337
Brussel	2,002	3,257	3,026	4,673	3,672

In an intermediate group would come Common Mussel, and some of the St. Juliens, but the latter as seedlings are so variable that it would be unwise to generalise about them.

Common Plum and Brussel would form a distinctly dwarfing group, to which apparently might be added St. Julien de Toulouse and at least two of the East Malling St. Julien selections—namely St. Juliens A and C.

It is quite certain that the limits of the range of vigour which it is possible to produce have not yet been reached at least at the dwarfing end. In July, 1925, Mr. E. G. Hunt, of Muddlebridge, Barnstaple, showed that it was possible to produce apparently healthy much dwarfed Cordon Plums upon seedling selections of Prunus Pumila.* In selecting and trying out seedling St. Juliens at East Malling at least one rootstock has already been found, which, if its early behaviour is maintained, would bid fair to being a real dwarfing root system amongst Plum stocks. That such stocks would have considerable value for quick cropping bush and cordon trees, provided they are sufficiently lasting, is obvious.

* See *The Gardeners' Chronicle*, vol. 78, p. 97—1/8/25.

TABLE IV.

Average Size of Heads and Stems of Victoria Plums on Various Stocks.

On Stock.	Unit.	Five Year Trees—Plot 15			Unit.	Four year Trees—Plot 20.			Unit.	Three year Trees—Plot 21.		
		Average Height in cm.	Average Spread in cm.	Girth at 9 in. in mm.		Average Height in cm.	Average Spread in cm.	Girth at 18in. in mm.		Average Height in cm.	Average Spread in cm.	Girth at 18in. in mm.
Myrobolan	(5)	283	340	298	(5)	263	238	206	(8)	118	105	123
Pershore	(7)	255	338	275	(9)	230	235	191	(5)	93	103	101
Brussel	(5)	245	295	243	(9)	183	183	170	(6)	95	98	113
Common	(5)	238	305	244	(8)	193	203	165	(5)	90	95	98

TABLE V.

Relative Vigour of Different Varieties of Plums on Various Rootstocks (five years).

On Stock.	Unit.	Pershore Egg.			Purple Egg.			Belle de Louvain.			Myrobolan (Cherry-Plum).		
		Average Height in cm.	Average Spread in cm.	Girth at 18in. in mm.	Average Height in cm.	Average Spread in cm.	Girth at 18in. in mm.	Average Height in cm.	Average Spread in cm.	Girth at 18in. in mm.			
Myrobolan ..	(7)	248	220	182	None worked			240 Unit (7)	155	191	270 Unit (3)	270	229
Pershore ..	(8)	213	210	174	195 Unit (11)	220	150	None worked					
Common ..	(7)	200	200	158	None Worked			200 Unit (8)	135	168	None worked		
Brussel ..	(7)	198	183	169	165 Unit (8)	180	132	183 Unit (4)	108	132	188 Unit (3)	190	132

Heights, Spreads and Girths.

Other measures of vigour, which may perhaps convey more to the fruit grower than actual length of wood made annually, such as average height and spread of the heads of the trees, and girth of stem at a given height, have been taken. Table IV. gives these figures for the same series of Victorias on two of the most vigorous and two of the least vigorous stocks.

In the case of Plums, this method, of putting the trees' head into a frame, as it were, seems to fall very well into line with the actual growth measurements, which latter became very difficult to take upon plum trees as they mature.

That it yields equally consistent results is confirmed by the behaviour of four other varieties (including a different species, Cerasifera) in Table V.

Table VI. gives the more complete picture for the important variety Czar.

Table VI.

Average size of Head and Stem of Czar Plums on Various Stocks (four years).

Stock.	Average Height in cm.	Average Spread in cm.	Girth at 18 in. in mm.
Myrobolan	285	180	200
Julien	230	168	175
Pershore	213	165	170
Brompton	203	158	169
Common Mussel ..	199	160	167
Common	165	115	131
Brussel	158	105	131

Again the trees on Myrobolan and Pershore are grouped at one end of the scale and Common and Brussel at the other, in the matter of size of tree. (See Figures 5 and 6).

Total Weight of Tree.

Another method of gauging vigour is that of taking total tree weight ; but except at the time of permanent planting this record can only be obtained at the termination of the experiment. The weight on leaving the nursery is perhaps rather a subject to be dealt with in a propagation paper, but when our second series of Czar plums was planted out at two years old, the weights from batches of sixty or more trees so generally confirmed the behaviour of the older trees under observation that we are constrained to quote them :

2 year Czars on Myrobolan (Selections A, B, C, D and E weight averaged)	.. ..	31.9 oz.
,, ,, Brompton	.. ..	27.2 oz.
,, ,, Common Mussel	.. ..	32.7 oz.
,, ,, Common	.. ..	25.2 oz.
,, ,, Brussel	.. ..	23.7 oz.

With the exception of the very heavy trees upon Common Mussel, the confirmation is complete. The exception is probably at least in part accounted for by the very fibrous and ramified nature of the Mussel roots rendering it impossible to clean them entirely from soil before weighing. To quote but one more instance, approximately sixty maiden trees of each of the six varieties, Victoria, Pershore, Monarch, Purple Egg, Pond's Seedling, and Blaisdon Red were individually weighed and measured upon a series of stocks.

When looked at as a series of trees upon any individual stock the results are as follows :—

For all Trees.

On Stock.	Average weight in oz.	Average Height in cm.
Myrobolan	10.4	172.7
Pershore	11.5	170.0
Common Mussel ..	8.8	145.3
Brussel	7.5	124.7
Common	6.6	119.3

Though examination of each individual combination would be repaid, this must be deferred until another occasion, and it need only be said that, with very few exceptions, they would still further bear out our general conclusions as to vigour.

Although there is sometimes considerable variation between individual trees in the same group, not always readily accounted for, it is obvious that the very general and repeated consistency of these average figures, representing at least four ways of expressing vigour, do really mean something.

These experimental plantations are still quite young, but observations of mature trees in commercial plantations, the rootstocks of which could be identified from suckers, have gone to confirm the actual data collected on these trees.

Habit of Growth.

Before leaving the question of growth, it is perhaps appropriate here to say a word with regard to certain manifestations in alteration of habit of growth which are undoubtedly the results of stock influence.

So far habit of growth appears to be modified in two directions. On some stocks (such as Myrobolan and Brompton) varieties produce noticeably more and longer lateral growths than on others (such as Pershore, Common Mussel or Brussel). It is not entirely a question of vigour apparently, since the vigorous Pershore does not produce the same lateral growth generally as the vigorous Brompton or Myrobolan.

Again, in the direction of uprightness or spreadingness there are very distinct modifications.

If, in the foregoing Tables IV. and V., for instance, the relative heights and spreads of trees on Brussel be compared with those on Pershore or Common Plum, the trees on Brussel will very generally be found to be more upright. On the Plot at Heston, Middlesex, originally kindly put at the writers' disposal by Sir W. J. Lobjoit, Victorias are planted alternately upon Pershore and Brussel and, in approaching the row, it appears from their habit of growth as if two different varieties were alternated.

The actual figures bear out the impression.

	Average Height.	Average Spread.
Victoria on Pershore (six trees) ..	212 cm.	279 cm.
,, Brussel (six trees) ..	205 cm.	234 cm.

(See also Figure 1.)

LONGEVITY.

As yet, the experimental plantations have given no indication as to the relative durability of trees upon different stocks except in so far as trees upon different stocks have shown an apparently varying capacity for taking and recovering from Silver Leaf disease (4 and 8)—a matter which will be dealt with in detail elsewhere.

It can, however, confidently be stated from general observation that even upon the most dwarfing stocks—Common and Brussel—trees of advanced age are commonly to be found where suitable varieties have been worked thereon.

Professor Hedrick(2) questioned the durability of the Mariana Stock on the light sandy soils of America, where it is apparently so suitable. This has made the writers naturally shy of recommending it, since until recently they had never seen it put to the test on an extensive scale in a commercial plantation. However, a visit to the Hollesley Bay Labour Colony, Suffolk, revealed the fact that Mr. H. Barton had worked the majority of his extensive plum plantations upon a stock he had found as a sucker locally, and reproduced readily from cuttings. A bed of this stock was immediately recognised as Mariana, though none of the very flourishing mature trees could be found suckering. But Hedrick claims that this stock rarely suckers. Certainly on this light sand at Hollesley at 15 years old the trees claimed to be worked on Mariana were flourishing.

TABLE VII.

Percentage of Plum Trees sending up Suckers at seven years old on Various Rootstocks.

Variety.	Victoria.	Czar.	Belle de Louvain.	Giant Prune.	Pershore Egg.	Denniston's Gage.	Myrobolan.	Black Bullace.
STOCK : Pershore	22	10	0	0	0	0	0	0
Brompton	30	0	0	20	0	0	22	0
Myrobolan (Seedlings)	40	46	43	—	29	12	14	33
St. Julien (Seedlings) ..	75	57	43	66	62	66	80	75
C. and B.L.S. Mussel	100	57	—	—	66	—	—	—
Common Plum ..	100	66	62	—	72	83	—	—
Brussel	100	50	50	83	100	100	100	—

SUCKER GROWTHS FROM THE ROOTSTOCK.

Many latter day horticultural writers were under the impression that the production of suckers from the rootstock was the result of raising that rootstock from a sucker, and that rootstocks reproduced from seed did not show this propensity (10). The records collected at East Malling on two three acre plantations of plums tend rather to prove that this annoying habit is a varietal one, in the main due to the type of rootstock itself, though possibly to some extent accentuated (or the reverse) by the scion worked upon it. At least in the early years Pershore and Brompton are slow to send up suckers in comparison with Common Mussel, Common Plum, and Brussel. Again, all these rootstocks seem to be more prone to send up suckers when budded with President than they do when worked with Rivers Prolific (see Table VIII.) ; whilst trees of Belle de Louvain and Czar sucker less freely on whatever stock than do trees of Victoria (see Table VII.).

TABLE VIII.

Percentage of trees sending up suckers in five years old Plantation.

Variety :	Victoria.	Rivers Prolific.	President.
STOCK :			
Pershore	0	9	36
Brompton	7	0	17
Myrobolan B. ..	6	0	5
Mariana	0	0	12
B.L.S. Mussel ..	45	0	100
C. Mussel	40	45	90
Common Plum ..	45	80	80
Brussel	70	70	100

Table VII. disposes of the idea that stocks raised from seed necessarily sucker less than those reproduced from suckers themselves. For instance, compare the behaviour of all varieties upon seedling St. Julien with the similar range on Pershore Egg stock.

Although having a bad reputation for suckering, amongst growers, the Myrobolan stocks have not been conspicuously notorious in this respect, and the selected and vegetatively raised Myrobolan B has sent up comparatively few growths.

The specimen trees of the different stocks growing on their own roots in the arboretum offer confirmation of the data collected in the field.

It is distinctly unfortunate that the Brussel and Common Plum, two stocks of such limited utility, should be so prolific in sucker growths, which indeed are often found in masses at considerable distances from the trees worked thereon, whilst the much sought after Pershore is so shy in this respect.

The observations upon suckering in these six acres of experimental plums, are fully borne out by facts in commercial plantations. Whilst suckers of Brussel and Common Plum abound, the comparative scarcity of Pershore and Brompton stocks speaks for itself.

That prolific suckering in the plantation is a nuisance, it is hardly necessary to stress, and it is unfortunately one of the disadvantages of the otherwise desirable Common Mussel Stock.

ROOTHOLD OR "ANCHORAGE" OF THE ROOTSTOCK.

That the tree's resistance to wind pressure is an important consideration to the commercial grower is undoubted, but it is not an easy matter for the investigator to record. However, the Research Station at East Malling is wind swept and the removal of tree stakes at certain periods usually has the desired results. Whilst at the one extreme, trees on Brussel and Pershore stocks have been notably poorly anchored, probably due in part in the case of Pershore to the one sided root system which they often develop, those on Brompton and Common Mussel have remained exceptionally firm. The variability, in this respect as in all others, has been very great amongst the trees on Seedling Myrobolan and St. Julien, and here again there seems no foundation for the tradition that seedlings *per se* are more firmly rooted than vegetatively raised stocks.

After a very severe gale in June, 1926, a complete survey of three acres of experimental Plums was made, and the following percentages of trees badly blown over were recorded :

Brussel	52%
Pershore	30%
Common Plum	18%
Myrobolan (Seedlings)	13%
St. Julien (Seedlings)	8%
Brompton	8%
Common Mussel	8%

FRUITFULNESS AS AFFECTED BY ROOTSTOCK.

As already mentioned, the oldest series of experimental trees on known rootstocks has only been *in situ* for eight seasons, and a considerable further period must elapse before any final judgment can be passed upon the effect of different rootstocks upon the productivity of particular varieties. However,

some indications of comparative fruitfulness have been obtained by a study of the blossoming habit of Victoria and other varieties on different rootstocks, and by an analysis of the early crop records.

Effect on Blossoming.

Observations upon the experimental trees have already shown stock influence to lie in three directions :

(*a*). The time of blossoming of any particular variety has varied with the rootstock upon which it is budded. Reference to this aspect of the investigation has already been made in a previous report (9).

It is in the early stages of blossom opening that the differences are most readily seen. In some seasons there has been nearly a week's difference between the opening of the first flowers of Victoria on Pershore and Mussel Stock as compared with the same variety on Brussel and Myrobolan. On the other hand, all the trees have reached approximately "full bloom" at very nearly the same date. In other seasons, the difference has been only a matter of a few days on the whole range of rootstocks under trial, but the indication at any rate suggests the possibility of further development along this line, which might be of economic significance.

Unfortunately, the time of blossoming of the rootstock itself appears to bear no relationship to its influence on any particular scion, since it will be noted that the late blossoming Pershore Egg stock appears to accelerate time of flowering, whilst the abnormally early Myrobolan (*P. Cerasifera*) delays it.

There are general indications that these stocks influence the time of blossoming of other varieties in the same direction as they do Victoria, though it is upon this variety that the most careful observations have been made.

(*b*). There are also notable differences in blossom production and the nature of the spurs in the early years of the same variety upon different stocks. These differences are quite obvious and when the trees were only four years old it was possible to collect some numerical data on Victorias expressing what the eye detected. The actual flowering spurs—all those growths from 6 to 30 centimetres were counted on all the trees. So were the growths between these lengths bearing no flowers—"infertile spurs." Finally, the number of blossoms on one year wood over 30 cms were counted—axillary fruit buds on main growths. The following table shows the contrast :

TABLE IX.

Analysis of Spurs on four year old Victoria Plums on Various Rootstocks.

On	Average Number of Short Flowering Spurs.		Av. No. of Axillary blossoms on 1-year wood.	Av. No. of Infertile Spurs.
	6 cm.	6–30 cm.		
Pershore ..	16	5	23	7
C. Mussel ..	17	7	47	2
Common ..	13	7	33	3
Brussel ..	12	4	11	7
Brompton ..	10	5	13	16
Myrobolan ..	9	5	7	23

Thus, whilst Victoria on Pershore, Common Mussel and Common Plum stocks had many short flowering spurs, and even a few axillary fruit buds on one year wood—notably on Common Mussel—there were very few infertile spurs. Trees worked upon Myrobolan and Brompton had, on the other hand, developed many of these infertile growths, whilst those on Brussel stock were comparatively poorly furnished throughout.

A few years later when it became an impossibility to take such data on the large number of trees involved, a general field survey was made. Extracts from the notes read as follows :

Victoria on Pershore—Blossoms on short spurs (clustered). These are distributed on all the older wood and even on long laterals.

Victoria on Myrobolan B—Very little blossom and few spurs on old wood. Many infertile laterals.

Victoria on Common Mussel—Mostly short clustered spurs.

Victoria on Brussel—Blossom on very short spurs, but, where strong, not at all well furnished.

Similar notes could be quoted for the varieties Czar, River's Early Prolific, and President, confirming the same general tendency. The trees on Mariana stock are described in many cases as " a mass of blossom both on old and one year wood—also many laterals well furnished with blossom."

Stock influence on blossoming, however, extends beyond the number and distribution of fruiting spurs.

(*c*). The actual number of the flowers upon the spurs themselves vary on a single variety worked upon different stocks. A careful analysis of the

number of flowers to each fruit bud, of the number of fruit buds per fruit spur, and of the number of flowers per spur, was made to test whether the general impression, that there were many more flowers per spur on the trees on Pershore and Common Mussel than there were upon Brussel or Myrobolan, was true.

The following figures based on a number of counts on Victoria in two seasons, express the situation clearly. Care was taken to make these observations upon shoots of similar length and strength.

TABLE X.

Average number of Flowers on Various Rootstocks.

On Stock.	Flowers per Bud.	Buds per Spur.	Flowers per Spur.
Common Mussel	1.8	3.9	7.3
Pershore	1.9	3.6	6.7
Brussel	1.9	2.5	4.7
Myrobolan ..	1.5	2.0	3.2

On the variety Czar there were practically double the number of flowers per bud on Pershore than there were on Brussel.

Figures 1, 2, and 3 all illustrate these observations upon different varieties.

EFFECT ON FRUITING.

It remains to be seen how far these differences in blossoming habit have been reflected in the first early crops of fruit. Table XI. summarises the crop performance of ten varieties on a range of these root stocks, over a block of three acres. The trees were planted as Maidens in 1921, and headed back as half standards. They bore their first few fruits in 1924 and their first considerable crop in 1926, but that of 1927 was practically ruined by late frosts. The actual average number of fruits per tree is given.

Generally speaking, the figures confirm the predictions made on blossom formation. Seven out of the ten varieties worked of Pershore stocks have given the heaviest crops, and in two other cases trees on that stock come third on the list. Unfortunately, only two varieties in this plantation were worked on Common Mussel but both these came second to Pershore in cropping. Out of five tests of trees on Common Plum, three took either first or second place. By contrast. compare the behaviour of varieties on Brussel and Myrobolan. Eight varieties were worked on Myrobolan, and six of these took from fourth to seventh place in

TABLE XI.

Average Number of Fruits per tree—4 years 1924-1927.

	Victoria.	Czar.	Pershore.	Dennistons Gage.	Belle de Louvain.	Giant Prune.	Purple Egg.	Cherry Plum (Myrobolan)	Shropshire Prune Damson	Black Bullace
Pershore	687	743	499	1284	89	678	665	628	72	2716*
C. Mussel	628	686	—	—	—	—	—	—	—	—
Common Plum ..	500	639	528	1200	138	—	—	—	—	—
Brompton	550	536	340	1160	67	525	562	122	—	2340
St. Julien (Seedling)	245	403	310	857	96	343	—	237	124	2290
Brussel	518	289	398	903	20	290	414	47	—	—
Myrobolan (Seedling)	420	372	297	704	12	—	—	66	177	2485

* In the case of Black Bullace the total number of fruits was estimated from the actual number in a given weight of fruit. Each fruit was not counted separately as on the other varieties.

the cropping list. Two curious exceptions are to be found in the behaviour of the two Insititia Plums, the Shropshire Prune cropping best on Myrobolan and the Black Bullace second best. In view of the partiality shown by Damson buds in the nursery for Prunus Cerasifera (Myrobolan) stocks, possibly some significance can also be attached to this cropping performance.

Again, eight varieties are worked on Brussel, seven of which take from fourth to seventh place in the cropping list. In view of the very widespread use of this root stock, these figures are somewhat surprising.

In view of the light crops so far picked and the incompleteness of many of the series of trees, it is unsafe to take the comparison further and attempt to draw too detailed conclusions, though such facts as the cropping performance of Myrobolan on Pershore as compared with Myrobolan worked on Myrobolan roots invite speculation. Perhaps the one root stock that has produced rather a better record than general field observations led the writers to expect is the Brompton, all nine varieties worked thereon taking from second to fourth place on the list ; in seven cases they are third. In view of the excellent anchorage of these roots, their freedom from suckers and their general adaptibility in the nursery, this is encouraging.

The crop records on the old planting of Victorias (1920) and the younger plantings of that variety, President's and River's Early Prolific strengthen these general conclusions about fruiting in the early years. The oldest planting of Victorias originally consisted of units of six or seven trees, planted in two gronps, but the intervention of disease has so reduced the numbers, in some cases to as low as three trees, that, although some fruits have been picked on the plot for six seasons, the publication of detailed figures is not justified. It is, however, notable that in 1922 and 23 the trees on Pershore, Mussel and Common Plum all bore a few fruits, and in 1924 had their first small crop, whilst, with the exception of a single tree amongst those on seedling Myrobolan, the remainder on that stock, on Brussel and Brompton were only just beginning to crop shyly.

The year 1925 proved a year of small crop, but again trees on Pershore, Mussel and Common Plums headed the list. The first really heavy crop of plums came in 1926, and although the Victorias on most stocks bore some fruit, these three stocks were still outstanding, and, but for the single exceptional tree on Seedling Myrobolan, the average for trees on that stock would have fallen far behind.

Finally, it was encouraging to find that, in a bad plum season such as 1927, the trees on Pershore, Mussel and Common Plum, once again gave most fruit.

The third series of experimental trees, which includes the varieties Victoria, Czar, President and Rivers' Early Prolific, planted 1922, has as yet had only very few fruits, but here again trees on Pershore, Common Mussel, Common Plum

and Brompton, have been responsible for the majority. One new outstanding feature is the very early cropping of varieties of Mariana stock. There are also indications amongst the trees on layered Myrobolan selections, confirming the observations on the trees on seedlings, that certain varieties of Myrobolan may be more fruitful than others.

Up to the present there is insufficient evidence of any effect of root stock upon the size of fruit. In the main, where there are any indications of such an influence, the size of fruit appears to be closely related to the weight and distribution of the crop on the tree. For instance, it seems probable that, on the average, the scattered plums of Czar on Myrobolan stocks are significantly larger than the typically clustered fruits from the heavy cropping Pershore.

Finally, it is worth noting that early cropping does not seem to be closely correlated with vigour of growth, or the reverse, since the trees worked on stocks having a widely different influence on growth are to be found both in the shy and early bearing groups.

SUITABILITY OF THE DIFFERENT ROOT STOCKS.

In 1924, some recommendations, based on the observations set out in full in this paper, were published (11), as to the suitability of the various rootstocks. There seems no reason to qualify those deductions. As was then stated, unfortunately, in practice, at the moment, the availability of the different stocks must be taken into account. The facts in this report point to the greatly extended use of Pershore, Common Mussel and even Brompton stock, and to a more restricted use of Brussel, Common Plum and Myrobolan Seedlings.

Unfortunately, these recommendations are in direct contradiction to the existing supply, but it is to be hoped that an increased demand for trees on the more desirable roots will in time rectify the balance. In the meantime perhaps the following tabular summary may serve as some guide to the merits of the various stocks.

SUMMARY.

1. The species and varieties of root stocks used for plums are enumerated and discussed.

2. The reasons for using root stocks, and their desirable qualities are suggested.

3. The principal methods of propagation and sources of supply in Europe are described.

Variety.	Propagation.	Nursery Performance.	Young Trees.	Maturing Trees.	Established Trees.	Special Suitabilities.
Brompton.	Layers and Root Cuttings.	Consistently good with all varieties.	Vigorous.	Well anchored, large trees, moderate crops.	Sucker little—may crop heavily.	For weaker growing and heavy cropping varieties such as Czar.
Brussel.	Layers and Suckers.	Dries out readily. Incompatible with some varieties.	Medium. tendency to break at union.	Poor anchorage. Medium size. Mediocre crops.	Suckers prolific.	—
Common Plum.	Layers and Suckers.	Incompatible with many varieties such such as Czar, Ponds, President.	Somewhat dwarfed.	Well anchored. Medium size. Heavy crops.	Suckers prolific, medium size and heavy crop.	Suitable for some vigorous or slow cropping varieties, such as Victoria and Belle de Louvain.
Common Mussel.	Layers and Root Cuttings.	Tendency to dry out, consistently good with all varieties.	Vigorous and sturdy.	Well anchored. Medium size, heavy crops.	Some suckers, medium size, heavy crops, tendency to leaf scorch.	All varieties for early fruiting.
Myrobolan.	Generally very variable seedlings. Layers and wood cuttings recommended.	Consistently good with all varieties, though some seedlings show incompatibility.	Outstandingly vigorous.	Anchorage, variable—large trees, generally slow cropping.	Occasionally suckered. V. large size. Can crop heavily.	Suitable for weaker growing and heavy cropping varieties such as Czar and Purple Egg and for Damsons.
Pershore.	Suckers and Layers.	Consistently good with all varieties.	Vigorous and sturdy.	Moderate anchorage. Medium to large size. Heavy crops.	Sucker little. Medium to large size. Heavy crops.	All varieties tried.
St. Julien.	Generally very variable seedlings.	Good and bad varieties can be selected and raised vegetatively. St. Julien de Toulouse is one of the latter and often incompatible. Trees worked on seedling St. Julien are far too variable in growth and cropping to make generalization possible with many varieties.				
Damas.	Generally very variable seedlings.	Both Damas " noir " and " blanc " are equally variable, though the St. Julien de Toulouse—a layered stock—is sometimes known as Prunus Damas. Such very variable seedlings ought to be avoided.				

4. The behaviour of different root stocks in the nursery is compared, and the phenomenon of "incompatibility" of stock and scion described.

5. The work of previous investigators is summarised.

6. The plan of successional plantings at East Malling is detailed, and the statistical aspect of the records discussed.

7. Figures of the total length of wood growth, girth of stem, height and spread of the branches and total weight of tree, are presented to illustrate the effect of root stock upon the vigour of different varieties.

8. Stock effect on habit of growth is also described.

9. Propensities to a suckering habit are compared and shown to be varietal.

10. The question of firm roothold is shown to be varietal also.

11. The effect of different root stocks upon :—

(*a*) time of blossoming,

(*b*) blossom production and nature of spurs, and

(*c*) actual number of flowers, is illustrated.

12. The relative cropping power of young trees on different root stocks is compared.

13. Some general recommendations are made with regard to the specific uses of individual varieties of root stock.

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APPENDIX A.

As mentioned in the foregoing paper, the original units of trees planted for comparison have been so reduced by disease and in a few cases by "incompatibility," that the healthy remnant does not in most cases justify the application of a detailed statistical analysis. On the other hand, many of the differences brought about by rootstock are so obvious that it would appear quite safe to draw certain conclusions even from these small units. In the foregoing paper, the average lengths of wood growth, height and spread and girth have been used, and the figures which follow present, for different varieties, fair samples of the individual tree records from year to year, upon which these averages are based.

Only trees remaining healthy are included in the Tables. The full records for all the varieties and combinations discussed are available in the Station's Record Office for anyone caring to refer thereto.

INDIVIDUAL TREE RECORDS OF CZAR PLUM ON DIFFERENT ROOTSTOCKS.

Total Length of New Wood Growth each year.
(*recorded first four years after planting and then became too large*).

On Myrobolan Stock.

Row No.	Tree No.	1921.	1922.	1923.	1924.	Total.	No. of Fruits. Years 1924-7.
3	13	189	870	2.547	3,400	7,006	591
	14	292	1,045	2,554	3,646	7,537	334
	15	292	692	1,375	1,039	3,398	This tree showed silver leaf, 1925.
5	1	230	1,054	3,768	5,521	10,573	313
	3	271	755	1,932	3,071	6,029	222
	4	234	858	2,203	3,268	6,563	1,082
	13	267	656	1,307	2,392	4,622	526
27	3	238	825	2,058	3,509	6,630	115
Mean		252	844	2,218	3,231	6,545	455

On Pershore Stock.

Row No.	Tree No.	1921.	1922.	1923.	1924.	Total.	No. of Fruits. Years 1924-7.
3	2	176	500	1,323	1,620	3,619	588
	4	149	501	1,400	2,720	4,770	1,378
27	13	145	411	1.298	1,971	3,825	339
	14	177	567	1,684	2,566	4,994	456
	15	199	583	1,866	2,787	5,435	994
	16	135	425	1,617	2,213	4,390	508
Mean		164	498	1,531	2,313	4,506	743

On Common Plum Stock.

Row No.	Tree No.	1921.	1922.	1923.	1924.	Total.	No. of Fruits. Years 1924-7.
5	10	175	401	915	1.252	2,743	613
	11	88	325	795	1,150	2,358	579
	12	137	320	817	1,343	2,617	724
Mean		133	349	842	1,248	2,572	639

Individual Tree Records of Denniston's Superb Gage on Different Rootstocks.

Total Length of New Wood Growth each year.

On Myrobolan Stock.

Row No.	Tree No.	1921.	1922.	1923.	1924.	Total.	No. of Fruits. Years 1924-7.
4	13	113	819	2,156	3,210	6,298	783
	14	291	1,113	2,897	4,187	8,488	*—
	15	264	940	2,478	4,001	7,683	364
	16	234	1,186	2,885	4,791	9,096	654
26	1	203	1,002	2,914	2,675	8,794	1,079
	2	148	752	2,231	3,376	6,507	981
	3	208	864	2,314	3,185	6,571	737
	4	121	715	2,075	3,751	6,662	1,028
Mean		198	924	2,494	3,896	7,512	804

* This tree developed Silver Leaf severely before the fruiting period and is not included in the Mean.

On Pershore Stock.

Row No.	Tree No.	1921.	1922.	1923.	1924.	Total.	No. of Fruits. Years 1924-7.
4	1	249	1,097	2,730	3,944	8,020	1,571
	2	197	1,180	2,658	3,238	7,273	1,846
	3	164	757	2,360	3,188	6,469	1,336
26	14	192	516	1,785	1,956	4,449	756
	15	143	741	2,008	2,428	5,320	1,272
	16	224	916	2,072	2,675	5,887	913
Mean		195	868	2,269	2,905	6,237	1,283

On Brussels Stock.

Row No.	Tree No.	1921.	1922.	1923.	1924.	Total.	No. of Fruits. Years 1924-7.
15	1	119	679	1,536	2,462	4,796	977
	3	127	593	1,558	2,866	5,144	1,148
	5	49	399	1,134	2,083	3,665	815
	7	94	575	1,530	2,133	4,332	986
	9	150	660	1,592	2,264	4,666	635
	11	92	645	1,655	2,504	4,896	1,050
	13	134	723	1,696	2,661	5,214	711
Mean		109	611	1,529	2,424	4,673	903

INDIVIDUAL TREE RECORDS OF VICTORIA PLUM ON DIFFERENT ROOTSTOCKS.

On Myrobolan Stock.

Row No.	Tree No.	Head of Tree.		Girth of Stem.
		Height. cms.	Spread. cms.	mms.
7	15	263	248	205
	16	255	195	190
23	2	270	285	240
	3	293	270	225
	4	233	195	170
Mean		263	239	206

On Pershore Stock.

Row No.	Tree No.	Head of Tree.		Girth of Stem.
		Height. cms.	Spread. cms.	mms.
7	1	285	270	233
	2	233	255	197
	3	225	233	194
	4	203	255	190
9	1	210	240	170
	2	240	278	180
	3	233	180	168
23	13	225	225	202
	14	218	188	186
Mean		230	236	191

On Common Plum Stock.

Row No.	Tree No.	Head of Tree.		Girth of Stem.
		Height. cms.	Spread. cms.	mms.
19	1	218	233	168
	2	195	195	156
	3	203	180	152
	4	158	180	150
21	9	203	233	188
	10	188	195	176
	11	195	180	160
	12	180	218	172
Mean		192	202	165

INDIVIDUAL TREE RECORDS OF PERSHORE PLUM ON DIFFERENT ROOTSTOCKS.

On Myrobolan Stock.

Row No.	Tree No.	Head of Tree.		Girth of Stem.
		Height. cms.	Spread. cms.	mms.
10	13	240	248	181
	14	240	225	180
	16	240	195	181
20	1	255	255	178
	2	225	210	188
	3	240	210	162
	4	248	203	205
Mean		241	221	182

On Common Plum Stock.

Row No.	Tree No.	Head of Tree.		Girth of Tree.
		Height. cms.	Spread. cms.	mms.
12	9	210	203	164
	10	210	158	150
	11	203	218	170
18	1	195	240	170
	2	210	210	158
	3	188	165	145
	4	195	210	152
Mean.		202	200	158

On Brussel Stock.

Row No.	Tree No.	Head of Tree.		Girth of Stem.
		Height. cms.	Spread. cms.	mms.
12	14	210	180	180
	15	195	210	175
	16	203	180	170
18	5	188	180	180
	6	195	135	156
	7	195	188	160
	8	195	210	166
Mean		197	183	169

APPENDIX B.

By T. N. HOBLYN.

Statistical analysis of the records dealt with in the foregoing paper is a somewhat complicated matter. In the first place, although each combination of variety and rootstock was repeated in two places on the ground, in no case can the sample be described as truly random. In the second place the ravages of disease have so reduced the number of trees, that the remainder, while certainly in some cases very suggestive of effect and in others showing obviously significant differences between different combinations of stock and scion, do not permit of a detailed statistical examination.

In two cases, at least, however, in the third and youngest planting, there remain a sufficient unit of Rivers' Early Prolific and President Plums on most of the rootstocks under trial to enable fairly clear significant results to be obtained. The method used to show this significance is not the ordinary calculation of the standard error of the difference on the assumption that the values are normally distributed, since such an estimation is only reasonably accurate where the samples are large. As in this case we have to deal with small samples, an extension of Students' method of treating such samples, given by R. A. Fisher (*a*)*, for finding the Standard error of the difference between two means, must be used.

The formulæ necessary are :—

$$s^2\left(\frac{1}{n_1+1}+\frac{1}{n_2+1}\right) = \frac{n_1+n_2+2}{(n_1+1)\ (n_2+1)\ (n_1+n_2)}\left\{S(x-\bar{x})^2 + S(x'-\bar{x}')^2\right\}$$

where $\bar{x}$ is the mean of Sample I.;

$\bar{x}'$ is the mean of Sample II.

(n_1+1) = the number of observations in Sample I.

(n_2+1) the number of observations in Sample II.

$S(x-\bar{x})^2$ and $S(x'-\bar{x}')^2$ = the sums of the squared deviations from the two means.

and 's' is the estimate of the Standard error of the difference.

From this formula 't' $= \dfrac{(\bar{x}-\bar{x}')}{s}\sqrt{\dfrac{(n_1+1)\ (n_2+1)}{n_1+n_2+2}}$

Fisher gives a table of values of "t" for $P=0.9$ to $P=0.01$ where P is the probability of such values of 't' occurring by chance for each value of 'n'. In the above case the table is entered with $n=(n_1+n_2)$. A difference is said to

* (a) *Ref. Statistical Methods for Research Workers. R. A. Fisher.* (Oliver & Boyd.)

be significant if 't' exceeds the value given in the Table for P = .05 ; the odds are then about 20 to 1 against such a value of 't' being obtained by chance.

The Table shows the means and standard errors for the Total Wood Growth of two varieties of plum on eight different rootstocks. Where two or more means are bracketed together no significant difference between them exists.

In general the rootstocks seem to fall into three groups with Myrobolan B. always producing the largest trees and Common and Brussel the smallest.

Total Length of Wood Growth of Five -Year Old Plum Trees on Different Rootstocks.

Rivers' Early Prolific.

Rootstock.	Unit.	Mean (metres).	S.E.
Myrobolan B.	11	52.62	1.42
Marianna	10	51.13	3.30
B.L. Mussel	11	36.92	2.50
Common Mussel	11	31.87	1.83
Brompton	11	27.91	3.17
Common Plum	11	27.88	1.92
Brussel	11	24.90	2.02
Pershore	11	24.20	2.03

President.

Rootstock.	Unit.	Mean (metres).	S.E.
Myrobolan B.	11	56.86	2.79
Pershore	11	52.09	3.85
Brompton	11	48.62	3.73
B.L. Mussel	11	45.43	3.06
Marianna	8	45.20	5.06
Common Mussel	11	44.95	2.37
Common Plum	7	24.96	3.40
Brussel	9	17.40	1.75

Brief reference can only be made here to a second method of dealing with data such as the above. This method is another developed by R. A. Fisher (*a*) and is known as the "analysis of variance." The "variance," which is simply the mean of the squared deviations from the mean, may be defined as the "quanity of variation" in the subject under consideration. Considering the above experiment as a whole, there are three main factors which contribute to the variation in the trees under trial.

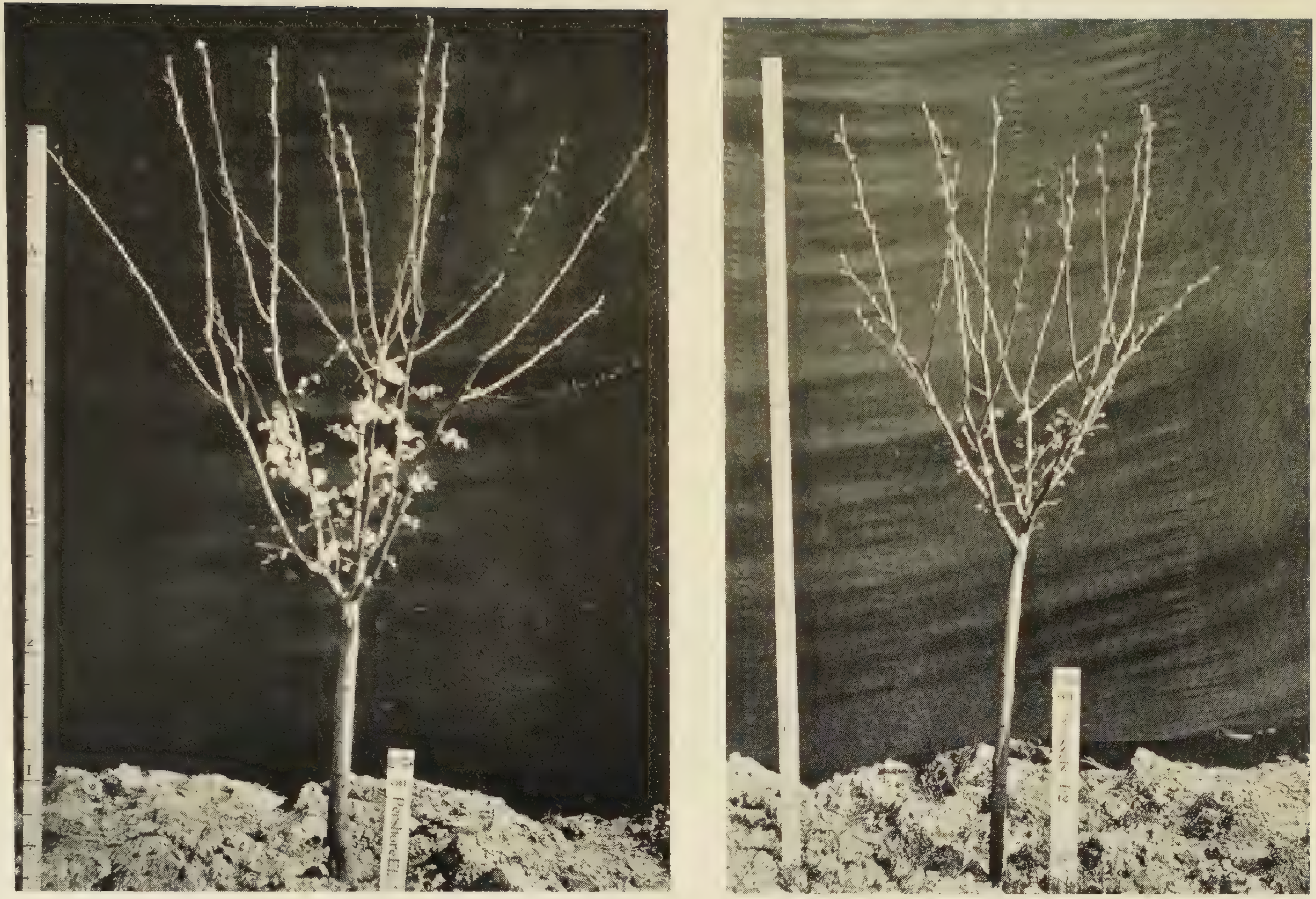

FIG. 1.

Typical six year old Victoria Plum trees on Pershore (left) and Brussel (right) rootstocks. Note stock effect upon relative time of blossom opening, character of flowering and habit of growth.

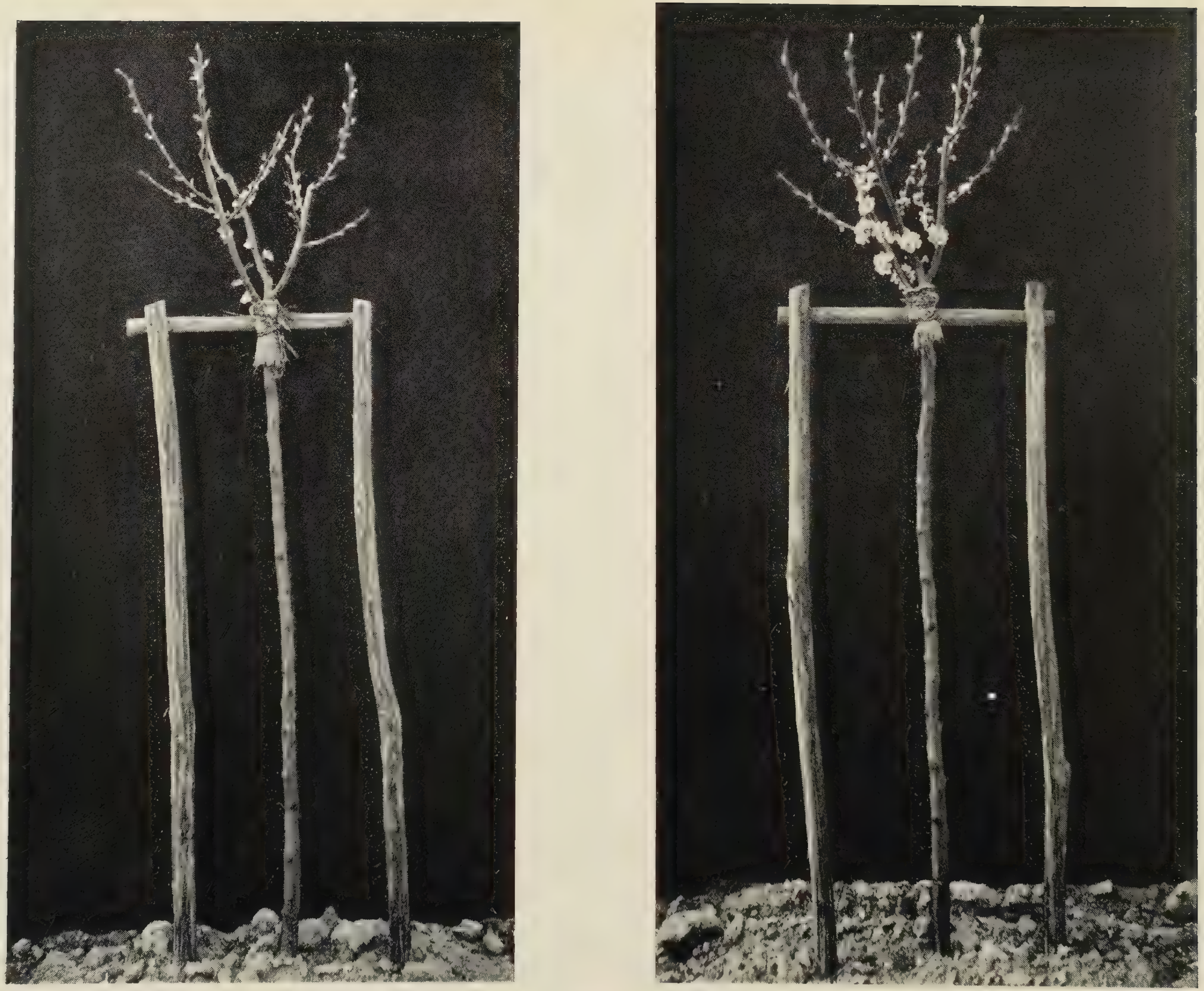

Fig. 2.

President Plum on Myrobolan B. rootstock (left) showing scanty blossom and barren laterals at three years. Compare same variety

Fig. 3.

Branch of Cherry Plum (Myrobolan).

Left—from typical tree on Pershore stock.
Right—from typical tree on Myrobolan stock showing much more scattered bloom.

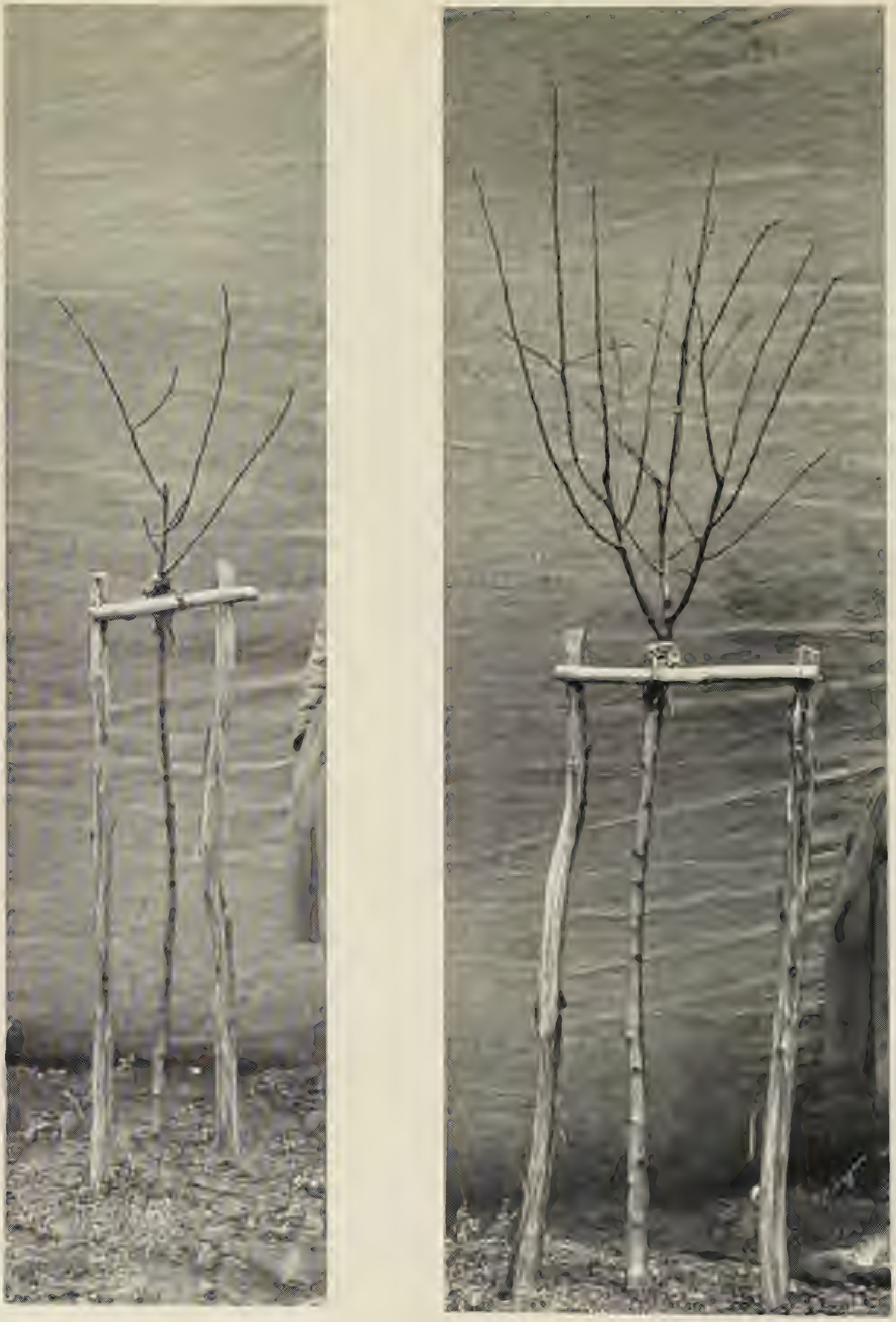

FIG. 4.
President Plum on Brussel stock (left), showing typical symptoms of "incompatibility" as compared with normal tree on Brompton stock (right)

FIG. 5.

Compare vigour of Czar Plum, eight years old, on Common Plum stock (left) and Pershore stock (right). See also Fig. 6 showing same variety on Myrobolan stock.

Fig. [illegible]

Czar Plum on Myrobolan stock. Compare with Fig. 5 (same scale).

(i). The variation caused by including different varieties or treatments in the experiment.

(ii.) That caused by heterogeniety of the soil.

(iii.) The variation due to random sampling and other uncontrolled factors.

Where a trial has been specially planned, it is possible to isolate the variance contributed by each of these three factors causing variation and to test whether (i.) and (ii.) are differing significantly from (iii.) i.e., whether the varieties or treatments differ significantly from one another and whether the heterogeniety of the soil is marked or not.

In the above case however, it is not possible to disentangle the variance of the soil from that due to random sampling, but the total variation due to differences in treatment may be isolated and further sub-divided into its component parts :—

(i.) due to differences in vigour between the two varieties of plum.

(ii.) due to differences in vigour induced by the various rootstocks.

(iii.) due to the differential response of the two varieties of plum to the different rootstocks upon which they are " worked."

It is not proposed to go into the details of the analysis here, since the space occupied would be too great. It may however be stated that this method applied to the two varieties of plum, Rivers' Early Prolific and President on the five rootstocks, of each of which there remain eleven trees, showed not only that there are very significant differences in vigour between the two varieties, and also between trees grown on the five different rootstocks, but also that there is here a clear case of two varieties of plum responding differently to different rootstocks.

To be precise, Rivers' Early Prolific, the weaker growing variety, receives a greater stimulus by being worked on Myrobolan B., than does the more vigorous variety President ; on the other hand, while President is rendered more vigorous by Pershore, Rivers' Early Prolific is clearly dwarfed by this rootstock at least under the conditions of this trial.

(*Received 18/1/28.*)

FACTORS GOVERNING FRUIT BUD FORMATION.

VIII.*

THE SEASONAL ELONGATION GROWTH OF APPLE VARIETIES ON SOME VEGETATIVE ROOTSTOCKS; AND ITS POSSIBLE RELATION TO FRUIT BUD FORMATION.

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Introduction.

The vegetatively propagated rootstocks have been shown to have effects other than upon the vigour of the scion (6 and 7). They have been shown to influence the precocity with which a tree comes into bearing, and under certain conditions the time of blossoming. Since some rootstocks markedly increase the number of fruit buds formed in the early life of the tree it was considered desirable to ascertain whether these differences were directly related to differences in the seasonal growth curves as affected by rootstock influence. It is well known that the elongation growth of the shoots, and the growth of the tree as a whole exhibits well marked growth periods. When the total length, or height, or weight or any other factor is measured at regular intervals during the season and the measurements plotted against time, the curve so obtained shows one, or more characteristic S-shaped configurations. These are known as the curves of the Sachs grand growth period. Each S corresponds to period of growth during which the growth rate starts at a minimum, gradually increases in velocity and after attaining a maximum gradually decreases again.

It is conceivable that different varieties may have their maximum growth periods at different times during the season when growing upon a uniform vegetatively propagated rootstock. An individual variety also may have its maximum growing period at different times when growing upon different rootstocks. In the case of the greater amount of shoot growth associated with the use of some rootstocks, it may well be asked whether this is due to an earlier start in spring, a more prolonged seasonal growing period or a greater weekly growth increment over the whole or part of the period. The present paper is primarily an attempt to deal with these questions.

* The previous numbers of this series of papers have been written by several workers at The Research Station, Long Ashton, and have appeared from time to time in the Annual Reports of The Research Station.

This paper treats of a long period investigation at Long Ashton, the data having been accumulated at various times by several workers. The work was begun as a continuation of that on "The Factors Governing Fruit-bud Formation" initiated by Barker and Lees (1). In 1919, individual trees of several varieties of apple growing upon a uniform rootstock (English Broadleaf) were selected for measurement by Mr. A. H. Lees. The data collected in 1919 by Mr. Lees are given in Table I. and in Text Figures 1 and 2. Further measurements were taken in 1923 by Mr. W. H. Neild, Experiments Officer, working under the direction of Professor B. T. P. Barker. The data collected in 1923 are recorded in Tables II. and III. and Text Figures 3 and 4. Further measurements along the same general lines were taken in 1925 by Mr. E. Ball and his data are given in Table IV. and Figures 5 and 6. In 1926 the measurements were continued by Mr. E. Ball and the present writer: the latter has been left to make the final analysis of the data accumulated as outlined above. In the following sections the data are presented in historical sequence and the general tentative conclusions are indicated at the close of each section.

THE NORMAL GROWING PERIOD OF SOME VARIETIES OF APPLES AT LONG ASHTON FROM RECORDS TAKEN IN 1919 BY MR. A. H. LEES.

Table I. and Text Figures 1 and 2 give the growth data for apple trees at Long Ashton collected during 1919 by Mr. A. H. Lees. Barker and Lees (1) have pointed out, however, that the growth conditions at this Research Station are probably somewhat different from those of the larger fruit growing districts of England. The year 1919, was, however, a fairly average year for Long Ashton, particularly as regards the summer rainfall which as Lees (11) points out is a factor of considerable importance. While it is impossible to draw any but tentative conclusions from these data alone, yet when considered along with the data presented in the subsequent sections of this paper they permit of the general interpretation put forward.

Table I. gives the measurements from which the graphs of Figures 1 and 2 are constructed. Five trees of each variety—Bramley's Seedling, Bismarck, Cox's Orange Pippin and Lord Hindlip—were selected and two leading shoots of each of these trees were labelled. These trees were all growing upon a uniform rootstock. (English Broadleaf.) The length from the last leaf scar of the 1918 extension growth to the base of the youngest discernible leaf petiole was taken as the unit for measurement during the period from the 25th of May to the 7th of August. From March 17th to May 22nd the measurements were from the leaf scar to the tip of the unfolding bud. The figures in Table I. are the averages of the number of shoots there indicated. For the present purpose it does not appear to be worth while to treat these data statistically. While it is true that there is a certain amount of variation between

the total amounts of extension growth made on the individual trees, yet the salient features of the growth curves which concern us at the moment are of sufficient magnitude and consistency to allow of the present discussion without statistical analysis.

It is seen from Table I. that the actual amount of extension growth made by these four varieties is not very different. The greatest variation is between Bismarck and Hindlip, which on the average made 29.1 and 36.0 cms. extension growth respectively. The other two varieties made an equal amount, namely 33.3 cms. The growth in length of the buds during the period March to May was almost parallel for all four varieties. The maximum growth of these buds took place between the 10th and the 20th of May. The comparative lateness of the date upon which any increase in length was recorded is interesting. This date was the 8th of May for all four varieties. The buds, however, were obviously swelling several weeks before any measurable extension growth took place. Reference to Figures 1 and 2 shows that in contrast to the parallel development of the varieties during the "early growth" period, the subsequent weekly shoot growth shows considerable divergence. Each variety apparently has its own particular growth curve. Thus, Bramley's Seedling and Cox's Orange Pippin have somewhat parallel curves which show a rapid and continuous rise to a maximum on June 12th, 1919, after which they fall off to July 3rd but show a marked secondary rise on July 10th. After July 10th, they both fall rapidly and completely away. The curve for Bismarck while it does not quite attain the maximum height reached by the Cox's Orange Pippin and Bramley, yet after having attained its maximum it maintains it over a period of one week after which it falls off rapidly during one week. It then remains steady for three weeks after which it falls slowly and completely away. Hindlip has a very characteristic curve. It shows a slower and more gradual rise to its maximum which is not attained until three weeks later than that of Bramley and Cox, but when attained the growth is sustained at this maximum rate for a period of three weeks, after which it falls off completely, almost within a week. Furthermore, the maximum growth rate of the Hindlip is considerably lower than that of the other three varieties (Fig. 2). It is interesting to note in passing that in spite of the lower maximum attained later in the season, Hindlip made the largest average total growth per shoot of the four varieties measured. A marked correlation between the seasonal growth of a variety and its characteristic fruiting habit is revealed by these data. It is hoped in a future communication to discuss this question of varietal fruiting habit in relation to its possible physiological basis.

It is clear from these data that the buds had a maximum growth period prior to the beginning of rapid shoot elongation. The rate of shoot growth increased from the end of May to about the middle of June for the varieties

Cox's Orange Pippin, Bramley's Seedling, and Bismarck, after which it fell off until the end of July. The variety Lord Hindlip was slower in attaining its maximum (July 3rd), but growth was maintained at a constant high level for three successive weeks, during which time the other varieties showed a slight recovery in growth but were on the whole declining rapidly. Thus, when worked upon a uniform stock—English Broadleaf—these varieties showed considerable individuality in their seasonal growth curves. The further discussion of these data is reserved until a later section.

Growth Measurements taken in 1923, by Professor Barker.

These measurements were taken in 1923 by Mr. W. H. Neild, Experiments Officer, under the direction of Professor Barker. The trees used were part of a block of three varieties—Bramley's Seedling, Lane's Prince Albert and Worcester Pearmain growing upon a number of vegetatively propagated rootstocks. The trees were planted as maidens in 1919. In 1923, the trees were all comparatively young and were growing vigorously. It will be noticed that as compared with the 1926 measurements those gathered in 1923 are somewhat irregular and do not include the early part of the growing season. This is due to the fact that in 1923 it was only intended to examine the differences in growth rates at the end of the season. Measurements were therefore taken at dates calculated to reveal any differences in growth rates at the end of the season that could be directly attributed to rootstock influence. The measurements taken in 1923 are recorded in Tables II. and III., and those of Table III. are shown graphically in Figs. 3 and 4. The data of Table II. are not plotted out because of lack of space but they give substantially the same curves and allow of the same interpretation as the data of Table III. Furthermore, in 1923 data were obtained of these varieties growing upon a number of rootstocks other than those shown in Tables II. and III. These also support the following statements from the data given.

The measurements gathered in 1923 of Lane's Prince Albert and Worcester Pearmain growing upon a range of vegetative stocks, show, within the varieties, growth curves associated with particular rootstocks, and also distinct varietal growth curves in addition to those of rootstock influence. That is, when the growth curves for these two varieties growing upon a uniform rootstock are plotted upon the same graph, they are seen to show differences that are best explained as differences due to variety characteristics.

The rootstock—Malling Type IX—is invariably associated with the least amount of total growth made by the shoots of both varieties. This appears due in a small measure to a slower rate of growth during the early part of the season, but more particularly to a relatively early falling off in the growth rate. Thus in the case of Lane's Prince Albert, the trees growing on the Malling Type IX.

rootstock had almost ceased elongation growth on the 9th of August, 1923, whereas those on the Malling Type II. had only begun to slow down a little on August 9th, and it was not until the 1st of September that elongation growth had almost ceased in the trees of this variety upon this latter rootstock. In the case of the trees on the Malling Type I. rootstock, growth continued vigorously until the 1st of September. Thus the trees on the latter rootstock were growing rapidly for three weeks after the same variety growing upon the Malling Type IX. rootstock had almost ceased growth. This is equally true for the variety Worcester Pearmain except that there is rather less difference between the Malling Types II. and I. than in the case of Lane's Prince Albert. It should also be pointed out that in every case the average amount of shoot growth is less for the variety Worcester Pearmain than for Lane's Prince Albert upon the same rootstock. As pointed out earlier this fact is indicative of a distinct variety factor, manifested throughout the range of rootstock influence.

The main points brought out by these measurements are, (*a*) the same varieties when growing upon different rootstocks have different seasonal growth curves. (*b*) The average amount of shoot growth made during the season varies with the different rootstocks. (*c*) Elongation growth may slow down and eventually cease as much as three weeks earlier in the trees on some rootstocks than on others and (*e*) Varieties retain an individuality, inasmuch as a uniform rootstock does not induce a similar amount of elongation growth with all varieties, e.g., the variety Worcester Pearmain produces less elongation growth on every stock than does Lane's Prince Albert.

Growth Measurements taken in 1925, by Mr. E. Ball.

These measurements were taken in 1925 by Mr. E. Ball. The trees are from the same experimental plot as those used for the records obtained in 1923 by Professor Barker. Two trees of each variety, Lane's Prince Albert and Bramley's Seedling were selected growing upon the several rootstocks. Twelve leading shoots of each tree were labelled for measurement. Measurements were taken on the dates shown, and are recorded in Table IV. and graphically in Figs. 5 and 6.

The remarks made in connection with the records taken in 1923 apply to these made in 1925. There are some differences, however, which are worth pointing out at this juncture. It will be seen that the growth curves of the trees growing upon Malling Type IX. are now still further separated from those of the same variety growing upon the other rootstocks. The measurements taken in 1925 were begun even later than those taken in 1923. This accounts for the almost horizontal curves of Figs. 5 and 6. It is clear, however, that the trees on the Malling Type IX. rootstock ceased elongation growth earlier than those on the other two rootstocks. These 1925 measurements also show the varietal

characteristics maintained throughout the range of rootstock influence as when measured in 1923. The generalisations contained in the closing paragraph of the last section apply equally to the data recorded in the present one. Their significance is more fully discussed in a later section.

GROWTH MEASUREMENTS TAKEN IN 1926, BY MR. E. BALL AND T. SWARBRICK.

The 1926 measurements were taken by Mr. E. Ball and the present writer and are a direct continuation of the previous work already given. This earlier work was sufficient to establish the broad outlines as given in the closing paragraph of the section that treats of the 1923 data. The previous measurements, however, were too scattered and began too late in the growing season to allow of detailed analysis. In 1926 it was thought desirable to obtain a more complete record of the differential effect of rootstock upon the growing period of the scion variety. In 1926 therefore, further trees in the same block as that used for obtaining the 1923 and 1925 data were selected for measurement. At that time the trees were seven years old from planting and were coming more or less into bearing. Three varieties were selected, namely, Lane's Prince Albert, Worcester Pearmain and Bramley's Seedling. Trees of each of these varieties growing upon each of four rootstocks, viz., Malling Types I., II., IX. and XII. were selected as exhibiting a wide range of vigour. (Types I. and II. as being of medium, Type IX. of dwarfing, and Type XII. of vigorous habit.) Three trees of each variety growing upon each rootstock were selected. These trees were those of average size and vigour for the stock in question, the largest and smallest trees being neglected. Eight principal "leader" shoots of each tree were selected and growth elongation measurements were taken at weekly intervals during the season. Thus measurements were obtained of twenty-four shoots of each scion variety growing on each of the above four rootstocks. The branches of the Lane's and Worcester's were pruned in April by having about one-third of the previous season's extension growth removed. This delayed the date at which it was possible to begin the measurements, because of the tardiness of the lateral buds of the Worcester to break following the pruning. The Bramleys were not pruned. The more advanced terminal buds of unpruned trees were beginning to swell about the middle of March, but measurements were not begun upon these experimental trees until June 1st. By this date the buds left in a terminal position by pruning had made from 3.0 to 7.0 cms. of elongation growth, the lower figure being that for Worcester. The measurements were taken in each case from the top of the 1925 leaf scar to the base of the last open leaf.

The data are given in Tables V.-IX. and the averages are calculated and shown graphically in Figs. 7-12. The nature of this work does not appear to demand the determination of probable error figures. The consistency of the

main points shown throughout three years investigation is of sufficient significance for the present discussion. Reference to Tables V., VI. and VII. will show, moreover, that the average for the eight shoots of each tree shows but little variation from tree to tree, when any one variety upon any one stock is considered. In the nature of the case this was to be expected since the uniform sized trees were selected in the first place. It is interesting to note that as in the previous cases the averages for the eight shoots per tree are much closer at the beginning of the season than they are later in the season. That is, as the season advances the difference between trees and the effect of rootstock influence becomes more pronounced. It ought also to be pointed out that in some cases the majority of the lateral buds of the variety Worcester Pearmain were flower buds and it was necessary therefore to measure the shoots arising from the bourses.

Considering first the average total growth curves it should be borne in mind that in each case twenty-four selected leading shoots were measured, and that their average growth gives little or no indication of the *total* shoot growth made by the tree as a whole. Differences in variety habit—as for instance the number of lateral buds that develop into shoots—are maintained throughout the range of rootstocks upon which the varieties are worked. Varieties tend always to have the same relative growth habit both as regards their form and manner of branching when they are growing upon a uniform rootstock. Because of the great differences in natural branching habit of varieties the total shoot growth per tree made by the varieties might show much greater differences than are revealed by the average shoot growth figures for selected leader shoots here recorded.

It is clear from Tables V.-IX. and Figs. 7, 8 and 9, that while the varieties began growth at different times, any one variety tended to begin growth about the same time upon all four rootstocks used in these experiments. This in contrast with the reported observations from East Malling. Under Long Ashton conditions the differences as regards time of bud break are more evident between varieties irrespective of the rootstock upon which they are growing, than between trees of a variety growing upon a range of uniform vegetative rootstocks. In the case of Bramley's Seedling and Worcester Pearmain the growth curves for these varieties upon all four rootstocks run parallel and very close together during the early part of the growing season. This is also true for the variety Lane's Prince Albert growing upon the rootstocks Malling Types I., II. and XII. The trees of this variety upon Malling Type IX. rootstock show a divergent growth curve almost from the beginning of the season. This may be partly explained by the heavy crops borne by these trees. All varieties growing upon Type IX. rootstock show a very marked falling off in growth relatively early in the season, the growth curves becoming somewhat flattened about the end of July, whereas at this time the growth curves of the trees growing upon the other stocks were still rising.

This flattening of the curve early in the season was most pronounced in the variety Worcester Pearmain.

The total extension growth made by these selected leaders of the various varieties upon the several stocks is interesting. The variety Lane's Prince Albert made the most elongation growth on all stocks except Type IX., where Bramley's Seedling made an average of nine centimetres more.* This greater amount of elongation growth made by the Lane's Prince Albert is outstanding, particularly when it is remembered that this variety produces many more extension shoots than the other two. The diameter of the extension growth, however, is less than that of the Bramley shoots, so that from the data here available it is not possible to come to any decision as to which variety produces the greatest total yearly increase in tree substance. This study has revealed the inadequacy of elongation growth measurements as a measure of vigour when comparing varieties, when they are not considered in relation to such factors as the number of shoots produced and their relative thickness. In the matter of the average total growth made by the twenty-four leaders, the Lane's Prince Albert is closely followed by Bramley's Seedling. Worcester Pearmain made on the average 20.0 cms. less extension growth per shoot than either Lane's Prince Albert or Bramley's Seedling. Thus the total growth curves indicate the following points: (a) variety habit as regards extension shoots is evident throughout the range of rootstocks used, (b) under Long Ashton conditions a variety starts into extension growth at about the same time upon the different stocks under study, and the growth rate during the early part of the season shows very little difference between stocks, and (c) the total growth made by a variety upon the several stocks is determined not by a later start in spring but by a falling off in the growth rate early in the summer. (d) The trees on Type IX. stocks showed a marked slowing down in growth as early as July 27th and ceased growth as much as three weeks earlier than similar trees upon other stocks.

Considering next the curves for the average weekly growth increments as shown in Figures 10, 11 and 12 and Table IX. the similarity in the form of these curves is most outstanding. Thus the curves for the varieties when growing upon Type IX. are much lower than the others, in the case of Worcester and Lane's, indicating, of course, a much smaller weekly growth increment. As contrasted with the low level of the curve for a variety upon Type IX., the curves of the other three rootstocks keep fairly close together. With three exceptions the curves (twelve in all) rise and fall on the same dates. For example, they all fall on the 13th June and rise again for the 22nd, fall again on the 29th June and show a comparatively large rise on the 7th July. This outstanding periodicity in the curves, present as it is in all the varieties upon all the stocks, is undoubtedly indicative of some meteorological factor. Another

* This figure includes the shoots of the tree on the rouge stock (see Table VII.).

marked feature of these curves is the way in which they fall off on July 20th. After this date they slow down at different rates, the maximum falling off in the growth rate being in the case of trees on Malling Type IX. rootstock. There is indication of a secondary maximum in growth during late August or early September. Barker and Lees (2) in a previous investigation have already recorded the frequent occurrence of such a secondary growth period at this time. It will be noticed that the curves shown in Figures 10, 11 and 12 all end on August 17th. After this date there was a month's interval before the next measurements. Reference to Tables VII., VIII. and IX. will show that growth did not actually cease until the end of September on the trees of Malling Types I., II. and XII., but that it had ceased on Malling Type IX. at the beginning of September.

The total number of blossom clusters produced each year since planting for the trees measured in 1926, is given in Table X. It is shown that the trees growing upon Malling Type IX. produced more blossoms in 1923 and 1924 than trees of the same variety upon any other stock. In 1927, however, the trees upon Malling Type IX. did not show nearly the same superior number of flower clusters over the trees upon the other stocks. In fact the Lane's upon Types I. and II. and the Worcesters upon Type XII. showed more blossoms in spring, 1927, than trees of the same varieties upon Malling Type IX. There is, however, the important question of relative tree size. It is calculated from the figures given in Table X. that if the trees upon Malling IX. were of the same size as those upon Malling II. then in spring, 1927, they would have shown from two to four times as many flower clusters as the trees upon the latter stock. This calculated figure is given in Table X. in heavy type under the data for trees upon Malling Type IX. It is evident therefore from the data given in Tables V.-IX. that a rapid falling off in the growth rate early in the season is associated with a marked increase in the number of flower blossoms formed on the trees which show this kind of growth. It should be pointed out that the significant period as regards differences in the growth curves is about mid-July or earlier. Reference to Figures 7, 8 and 9 shows that at this time the curves for the trees upon Malling IX. were beginning to separate from the others, and by the beginning of August had taken up an almost horizontal position, whereas the other curves were still rising. Thus, the accumulated evidence gathered over a period of years, indicates a strong positive correlation between the cessation of length growth comparatively early in the season, and abundant flower bud formation.

Two points arising in connection with the data given in Table X. deserve special mention. The relatively low figure for total blossom production in the Bramley trees upon all stocks is undoubtedly due to the well known habit of this variety, namely very vigorous growth when young and much delayed bearing. The second point is the case of Lane's Prince Albert upon Malling Type B. The total number of blossoms produced by these trees upon this stock is

abnormally low and yet the growth curves for these trees are not materially different from those of the same variety upon Malling Types I. and II., which trees have produced a large number of blossoms. It is known that Malling B. is a very vigorously growing stock. The growth relation between the scion and stock in this case may be such that a large amount of the energy of the tree is being absorbed by the growth of this rootstock, and as a result there may not be the necessary accumulation of sugars in the shoots for abundant flower bud formation, even though there is less growth over the tree as a whole. As will be pointed out in a future communication there are several interesting and important varietal characteristics that need to be more thoroughly worked out. In any case the growth curves of Lane's upon Malling B. do not in any way approach those of the same variety upon Malling Type IX. In all the cases so far examined of the marked precocity of blossom bud formation associated with the use of some rootstocks, there is one particular distribution of the seasonal growth curve. The extension growth of leader shoots falls off rapidly during the period mid July to early August, and finally ceases ; in some cases this cessation is as much as three weeks earlier than that of similar shoots upon other rootstocks which do not have this influence upon flower bud formation during the early life of the tree.

A further point arising out of these measurements is the individuality of the scion variety. Thus, the average growth made by Worcester Pearmain when growing upon Malling Types I., II. and XII. (medium and strong rootstocks) is only about 14.0 cms. more than the growth made by the Lane's Prince Albert growing upon Type IX. (very dwarfing rootstock), and that notwithstanding the large number of shoots produced by this latter variety. Furthermore the Worcester Pearmains upon the stronger rootstocks made only 6.0 cms. more growth than the Bramley's Seedlings growing upon Malling Type IX. As indicated earlier, the order of the varieties as regards the average total shoot growth made by twenty-four selected leaders is (1) Lane's Prince Albert, (2) Bramley's Seedling, (3) Worcester Pearmain. The curves for each variety upon the several stocks have so nearly the same relative positions as to suggest that each scion variety has a definite "growth ability." In other words, varieties upon a common rootstock are not brought to a common level nor are all varieties affected equally in any one direction by a given rootstock.

DISCUSSION.

THE RELATION BETWEEN GROWTH AND FLOWER BUD FORMATION IN THE APPLE.

The factors governing fruit bud formation in apple trees are being slowly but surely elucidated. The more recent work has yielded a considerable amount of knowledge of the principles that underlie the practical methods that are adopted to increase fruit bud formation. It has been shown in a paper by Swarbrick (14)

and the workers to whom reference is there made; that under certain conditions ringing is a sure way of bringing about flower bud formation in over vegetative trees. Again it is well known that under circumstances of a relatively humid climate, or abundant nitrogen supplies, to grow trees in sod or under some form of cover crop system is more prolific of fruit bud formation than to grow them under conditions of clean cultivation. Furthermore, it has been recently pointed out by Lees (11) that in England the dry summers are more conducive to flower bud formation than are the wetter ones. The above conditions have all a common influence upon tree growth, in that they retard vegetative growth during the growing season and induce its cessation relatively early in the season.

A definite relation between elongation growth of spurs and fruit bud formation has been shown by Roberts (13) Dorsey and Knowlton (3) and others. Roberts found that the medium length spurs generally formed blossom buds whereas the shorter and longer ones generally did not. There was, in fact, a definite relation between the length of spur growth during the season and fruit bud formation. In this connection it appears advisable to insist upon some points that are often overlooked in discussions of flower bud formation. Most flower buds are terminal upon shoots of varying length. Even the so-called lateral flower buds are often found to have a much reduced axis. This axis becomes more evident when the buds break in the following spring. Again spurs are nothing more or less than lateral branches which for some reason have made but a limited amount of extension growth. Moreover, the flower bud of the apple differs materially from that of the plum, peach and cherry. The flower buds of the latter usually contain nothing but flowers, whereas those of the apple are almost invariably mixed buds, that is they contain leaves as well as flowers. Buds are also found in the axils of these leaves in the apple flower bud and it is from these that the spur growth may be continued indefinitely. This difference between the flower buds of the apple and the stone fruits is undoubtedly of considerable physiological and practical significance. Its relation to cultural practice lies in the probability that the practices best suited to induce flower bud formation in the one group may not be those most conducive to it in the other.

It is not intended here to discuss the various factors that are involved in the production of a full crop of fruit. It has been pointed out by several workers that the conditions most favourable to flower bud formation are not necessarily those most favourable to the set and maturation of fruit. The aim of the cultivator is to obtain a maximum amount of blossom under conditions most favourable to the maturation of an economic crop of fruit. However, flowers are a necessary preliminary to fruit, and the present part of this discussion is towards an understanding of the precocity of flower bud formation that is associated with certain rootstocks. This precocity is undoubtedly the result of some growth relation between rootstock and scion whereby conditions within

the plant are made favourable to flower bud formation during the very early life of the tree. The data presented shows that a marked falling off in the growth rate comparatively early in the season is invariably associated with the two varieties showing marked precocity when growing upon certain rootstocks known to induce it. Thus the growth relation of the scion to these precocious rootstocks, therefore, falls directly into line with that of ringing, growing trees in sod, and in the West of England a partial lack of water and semi-nitrogen starvation.

The rate at which growth falls off and finally ceases is a factor of considerable importance, and can be correlated with the persistent way in which some varieties form the majority of their fruit buds at the tips of comparatively long shoots. The habit of certain varieties, and of most varieties when young, to form fruit buds at the terminals of comparatively long shoots, is often correlated with a rather abrupt cessation of extension growth. Such an abrupt cessation of length growths results in the formation of a "rosette" of leaves around the base of the terminal bud. This rosette is the result of the failure of the upper internodes to elongate, and is in marked contrast with the results of a slow gradual cessation of length growth. In this latter case all the internodes are more or less elongated, and the terminal bud is subtended by one or at most two leaves which are often somewhat small. This situation in these two cases holds good irrespective of the time at which growth ceases. The data accumulated over several seasons and presented in this paper suggest that the precocity of flower bud formation induced in the scion by the use of some rootstocks is the result of a growth relation whereby shoot elongation is in some way slowed down and finally made to cease relatively early in the season. Conversely, the delayed bearing resulting from the use of other rootstocks appears associated with a larger amount of growth prolonged much later into the season.

The establishment of a definite relation between a rapid falling off in the growth rate of extension shoots of the apple early in the season and a propensity to fruit bud formation is of considerable importance to practice, in that bearing may be hastened or induced by appropriate cultural practices. With trees of full bearing age such practices have a special importance in the West of England where the usual warm moist August and September often leads to prolonged summer growth. This, when it occurs, has very adverse effects upon flower bud formation and is largely responsible for the abundance of "bare wood" so common in fruit trees in this locality. In fact, from many points of view it would appear that under the stress of climatic conditions in this area, it would be more profitable to grow apples under sod or some form of cover crop conditions. The necessary tree growth can be secured and regulated by applications of readily available nitrogenous manures and by occasional ploughing and cultivation. Local conditions must determine the precise methods adopted to control growth,

but the aim in mind must be a certain quality and amount of growth in the tree as a whole. Culture must be moulded so as to give this kind of growth as nearly as possible, and because of varying local soil, rainfall and climatic conditions generally, the necessary cultural practices will vary from place to place.

It has been shown previously by Swarbrick (15) in an anatomical and physiological study of the seasonal growth of the apple tree, that the cessation of elongation growth in the apple tree is followed by the cessation of diameter wood growth. This latter proceeds in a basipetal direction, that is from above downwards. Following upon the falling off of length growth a marked accumulation of reserve carbohydrate sets in. This reserve carbohydrate is deposited in the stem tissues in a basipetal direction. The region of the terminal buds of spurs or shoots that have made but little extension growth are the first to show this marked accumulation of reserve food substances. Later it occurs in the current season's growth. It is interesting and suggestive that in any given season flower buds are differentiated first of all on the spurs. Flower buds may be formed as much as a month later at the tips of comparatively long extension shoots or at the nodes of current season's growth. It is well known that spurs cease elongation growth very early in the season and it is most suggestive therefore that these should be the first to differentiate flower buds in the season.

That flower bud formation is a matter of nutrition must be patent to all after the wealth of research that has followed upon the pioneer work of Klebs (9) and Kraus and Kraybill (10). A great difficulty in plant as against animal physiology lies in the fact that the plant makes its own food while it uses it. Nutrition of plants thus becomes a most complex subject, involving as it does a balance between two separate and distinct processes, namely, photosynthesis and the utilisation or metabolism of the synthesised products. Small changes in the environment may render the photosynthetic mechanism less effective and at the same time enormously increase the metabolic rate. The effect upon the various growth activities may therefore be out of all proportion to the intensity of the stimulus. A further difficulty in plant nutrition is to follow with any degree of certainty the movement and use of the synthesised products in the plant body. Obviously these may be used in the formation of new permanent tissue such as wood or bark, they may be completely broken down to CO_2 and water in order to liberate the supplies of kinetic energy so necessary for all the purposes of life and growth, they may also be stored in a number of forms in the several tissues, and finally they may be precipitated along with other substances under the force of chemical laws and conditions. The time relation between the dominant phases of plant nutrition, growth, and flower bud formation, thus becomes important. The fact that the relation of carbohydrates and nitrogen to fruit bud formation appears to be a ratio rather than a question of absolute amounts, when considered along with the somewhat conflicting

chemical data upon the subject, leads one to suggest that the storage of easily detected reserve carbohydrates such as starch and cellulose and fruit bud formation are complimentary. They are apparently the result of a high concentration of soluble carbohydrates attained relatively early in the season. It is conceivable that an early falling off in the growth rate, or a slower rate of growth throughout the season would leave available a supply of organic food which in more vigorously growing trees would be built into permanent body tissue. At any rate it is clear that the conditions *immediately* preceding flower bud formation are not always decisive, for Roberts (12) showed that an appreciable number of flower buds were formed in spite of defoliation a week or so prior to the date upon which flower buds were first observed to differentiate. Harvey (8) points out that defoliation of spurs on June 12th-16th, 1919—fruit buds being usually present by July 5th—resulted in a decrease of some 40 to 60 per cent. of fruit buds as against spurs not defoliated. The point here stressed is that " . . . the change in the value of the (C/N) ratio was not strikingly large, at any rate not so large as the recorded effect of the same treatment on flower bud formation . . ." In the absence of detailed observation it is suggested that the real formulative period in flower bud initiation lies at some time previous to that at which the several anatomical bud changes can be observed. How much earlier will have to be decided by experiment and observation. It is probably significant that the growth of the apple varieties as shown in Figures 10, 11 and 12, was declining rapidly a week or more before the earliest possible date upon which flower buds could be expected to be present on these trees.

The data presented leads us to the conclusion that whatever may be the cause of the cessation of length growth in the terminal shoots, under the conditions of this study, the growth period of the tree as a whole and flower bud formation are positively correlated. A falling off of the growth rate early in the season appears very conducive to flower bud formation. In this connection observations cited by Chandler (2 pp. 14) that as trees grow older they cease length growth progressively earlier in the season, is of interest. It seems highly probable that the age at which a tree comes into bearing is influenced by this factor. It would be interesting to speculate further upon these relationships. It is, however, suggested as a working hypothesis that under normal English conditions the largest single formulative factor in flower bud initiation is the presence of soluble carbohydrates in the tissues of the bud region, some time prior to that at which the buds can be distinguished as flower buds by their anatomical characters.

In establishing the correlation between an early cessation of length growth and a marked propensity to flower bud formation in apple trees, the solution of the practical problem is advanced considerably because there are ways and methods that can be adopted to bring about this condition in the tree as a whole. As pointed out, earlier, however, the kind of growth most desired in apples may

not be at all desirable in plums. In fact there is evidence which strongly suggests that for the best results with plums it is desirable to have a considerable amount of length growth which should be continued later in the season than is desirable for apples. The manurial and cultural practices suitable for plums are in all probability not those most suitable for apples.

The examination of the data presented in this paper has also brought to light the importance of variety characteristics in relation to an interpretation of growth curves and the factors governing flower bud formation. There are also the further questions of the effects of malnutrition and acute water shortage upon the nature of the growth curve in relation to flower bud formation, and the possible causes of partial incompatibility of some varieties with rootstocks, which may bring about internal conditions of the tree that prevent flower bud formation. It is hoped to raise and discuss these points in a future communication under the present general title.

SUMMARY AND CONCLUSIONS.

The 1919 measurements indicate that when growing upon a uniform vegetative rootstock varieties have individual seasonal growth curves. This individuality may be directly correlated with certain peculiarities in the position of flower bud formation. This individuality is not much evident early but becomes more pronounced later in the growing season.

The 1923 and 1925 measurements show that (*a*) The same varieties growing upon different rootstocks have distinct growth curves indicative of an effect of rootstock upon the seasonal growth of the trees. (b) Different varieties growing upon the same rootstocks also have different growth curves which is indicative of a marked varietal growth ability. (c) The average amount of elongation growth made during the season may be directly correlated with the kind of rootstocks used. (d) Elongation growth of trees worked upon Malling Type IX. —which induces precocity of flower bud formation—showed a much more rapid and in some cases an earlier falling off in the growth rate of selected leader shoots. (e) Varieties maintain an individuality, e.g. Worcester Pearmain produced less individual leader shoot growth on every stock than Lane's Prince Albert.

The 1926 measurements show that (a) Variety characteristics as regards total amount of extension growth and manner of branching are retained on the several rootstocks. (b) Under Long Ashton conditions varieties start into growth about the same time upon the several rootstocks and except for the variety Lane's Prince Albert upon Malling Type IX. the growth during the early part of the season varies very little between the stocks. (c) The total amount of extension growth made by a variety upon the several rootstocks is determined not so much

by differences in the time at which the trees begin growth in spring, or by differences in the growth rate during the early part of the growing season, as by marked differences in the rate at which growth falls off during the latter part of the season and the time at which this falling off in growth begins. These points are also shown by the measurements taken in 1923 and 1925 by Professor Barker and Mr. E. Ball respectively.

A survey of the conditions that are most conducive to flower bud formation in the apple reveals the fact that they are those which tend to prevent excessive amounts of elongation growth and to induce the cessation of length growth comparatively early in the season. The same influence upon tree growth has been shown to result from the use of the vegetative rootstocks known to induce precocity of flower bud formation in young apple trees. It is suggested, therefore, that under normal English conditions a slower rate of growth during the early part of the season and more particularly an early cessation of length growth over the tree as a whole, give conditions within the tree which lead to abundant flower bud formation. It is recognised, of course, that under conditions of acute deficiency of one or more substance essential to growth, a tree may show the growth characteristics outlined above and yet there may be little or no flower bud formation. Under normal circumstances suitable for fruit culture it is believed, however, that the conditions here outlined are of fundamental significance. This supports the view of many growers that it is desirable to obtain the necessary amount of growth early in the season, and as far as possible, by suitable culture induce its cessation at a comparatively early part of the season. The actual amount of growth most desirable in apple trees will undoubtedly vary in the different localities and for different varieties. Under conditions such as usually prevail in some parts of England some form of a cover crop system appears to be a suitable way of controlling the amount of growth made by apple trees. The object is to obtain that amount and quality of growth in the tree as a whole, which experience and experiment show to be most favourable to flower bud formation. Cultural practice to this end must necessarily vary from place to place.

It is suggested that under normal conditions the formative influence in flower bud initiation in apples is probably a relation of soluble carbohydrates to nitrogen in the tissues present some time prior to that at which flower buds can be anatomically distinguished as such. Because of this, the application of culture to induce flower bud formation, a more accurate knowledge of the real formulative period is a matter of considerable importance.

The fruiting habit of certain varieties appear definitely related to their seasonal growth curves.

Varietal characteristics, persisting as they do over a wide range of conditions and rootstocks are of considerable importance.

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TABLE I.

Showing the average total extension growth of selected leader shoots of four varieties of apple growing upon a common stock (English Broadleaf), and the weekly growth increment of same.

1919. Measurement in cms.

Variety.	April 17	April 24	May 1	May 8	May 15	May 22	May 25	May 29	June 5	June 12	June 19	June 26	July 3	July 10	July 17	July 24	July 31	Aug. 7
Bramley Seedling (1)	0.5	0.7	1.0	1.7	4.0	* 5.6	† 1.8	5.1	9.9	16.3	19.8	24.2	25.2	28.2	30.6	31.9	32.6	33.3
Weekly growth ..	—	0.2	0.2	0.7	2.3	1.6	—	3.3	4.8	6.4	3.5	4.4	1.0	3.0	2.4	1.3	0.7	0.7
Bismarck (2)	0.3	0.3	0.4	0.8	1.9	4.3	0.8	4.0	7.0	13.0	19.2	21.5	23.6	25.6	27.6	28.7	29.0	29.1
Weekly Growth ..	—	—	—	0.1	0.4	1.1	—	3.2	3.0	6.0	6.2	2.3	2.1	2.0	2.0	1.1	0.3	0.1
Cox's Orange Pippin (2)	0.4	0.5	0.6	1.3	3.6	6.3	1.5	4.6	9.3	16.0	20.1	23.6	25.7	30.6	32.6	33.1	33.3	33.3
Weekly Growth ..	—	0.1	0.1	0.6	2.3	2.7	—	3.1	4.7	6.7	4.1	3.5	2.1	4.9	2.0	0.4	0.2	0.1
Lord Hindlip (3) ..	0.2	0.2	0.3	0.6	1.5	2.3	0.7	2.2	4.3	8.6	13.4	17.4	21.4	26.2	30.9	35.0	35.5	36.0
Weekly Growth ..	—	—	0.1	0.2	0.9	0.8	—	1.8	2.1	4.3	4.8	4.0	5.0	4.8	4.1	4.1	0.5	0.4

(1) Average of 7 shoots.
(2) ,, 10 ,,
(3) ,, 8 ,,

* Up to date measurement includes the terminal bud.
† Estimated length of axis on this date.

Table II.

Showing average total growth per shoot of all the shoots of one tree of each variety on several rootstocks.

1923. Measurements in cms.

Variety and Rootstock.	28 June	4 July	14 July	26 July	9 Aug.	1 Sept.	1 Nov.
Lane's Prince Albert.							
Malling Type IX... ..	7.5	8.5	12.5	13.5	15.0	16.2	16.4
Malling Type I.	21.8	26.8	44.4	51.0	58.8	67.0	68.6
Malling Type II. ..	17.0	19.8	28.0	33.0	36.0	40.8	41.2
Malling Type XII. ..	17.4	22.2	35.5	40.8	45.8	50.5	52.0
Malling Type XIII. ..	19.4	23.0	35.5	40.8	47.2	54.4	55.8
Bristol Type 5 ..	21.1	25.9	39.2	44.8	49.5	54.6	55.3
Worcester Pearmain.							
Malling Type IX. ..	—	—	17.6	18.8	19.4	21.2	21.6
Malling Type I. ..	—	—	12.8	24.8	29.2	32.4	33.4
Malling Type II. ..	—	—	15.2	17.2	23.4	33.4	33.6
Malling Type XII. ..	—	—	34.0	39.5	44.5	49.5	49.8
Bristol Type 5	—	—	25.5	30.3	34.1	—	—

Table III.

Showing the average total shoot growth per shoot of thirty-six shoots growing on three trees on each rootstock, i.e. twelve shoots per tree.

1923. Measurements in cms.

Variety and Rootstock.	28 June	4 July	14 July	26 July	9 Aug.	1 Sept.	2 Nov.
Lane's Prince Albert.							
Malling Type IX. ..	22.0	26.7	37.7	41.9	45.8	48.5	49.4
Malling Type I. ..	30.3	36.2	49.2	55.2	57.6	84.2	87.3
Malling Type II. ..	26.0	32.3	47.3	55.9	63.2	69.9	71.1
Malling Type XII. ..	26.1	32.5	50.2	57.9	66.2	75.4	77.4
Bristol Type 5	31.3	36.8	53.1	61.0	68.7	78.1	80.5
Worcester Pearmain.							
Malling Type IX. ..	—	—	29.0	34.6	37.9	39.9	39.9
Malling Type I. ..	—	—	28.3	33.0	43.7	59.8	61.3
Malling Type II. ..	—	—	30.7	36.4	42.9	54.4	54.9
Malling Type XII. ..	—	—	43.3	51.7	61.5	67.1	67.3
Bristol Type 5	—	—	42.9	49.8	57.5	60.6	61.3

TABLE IV.

Showing average total growth of twenty-four selected leading shoots of two trees of each variety (i.e. twelve shoots per tree).

1925. Averages in cms.

Variety and Rootstock.	16 July, 1925.	5 Aug., 1925.	14 Aug., 1925.	10 Sept., 1925.	7 Oct., 1925.	Order of Vigour.
Variety.— Lane's Prince Albert.						
Malling Type IX. ..	35.0	38.0	38.0	38.0	38.0	4
Malling Type II... ..	60.4	72.3	74.2	76.3	76.3	3
Malling Type I.	60.4	75.0	77.5	80.0	80.0	2
Bristol Type 5	68.3	81.7	83.3	85.9	86.0	1
Variety.— Bramley's Seedling.						
Malling Type IX. ..	42.0	46.7	47.0	47.0	47.0	4
Malling Type II. ..	51.3	61.3	63.1	67.3	68.8	2
Malling Type I. ..	56.3	71.3	75.6	82.5	83.5	1
Bristol Type 5	45.0	50.4	51.0	51.7	51.7*	3*

* Unfavourable location accounts for this abnormally low figure for this variety upon this stock.

TABLE V.

Showing the average total shoot growth of eight shoots of each of three trees of the variety Worcester Pearmain growing upon four different rootstocks.

1926. *Variety.*—Worcester Pearmain. Measurements in cms.

Stock	Tree No.	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Sept. 13 †	Sept. 28	Oct. 5
	9	1.3	3.9	6.8	10.7	14.3	20.9	27.0	35.9	39.6	43.9	46.8	50.0	56.2	58.7	59.4
Malling Type I.	12	1.5	3.8	6.5	10.9	14.8	22.3	28.3	35.8	39.8	42.7	45.2	47.6	51.0	51.7	51.9
	15	3.0	6.4	9.4	13.8	18.6	26.0	32.9	41.5	47.9	54.1	58.7	63.2	71.1	73.1	74.1
	16	1.4	4.6	6.7	10.2	14.0	22.0	28.7	36.7	41.3	46.2	50.4	53.1	57.8	59.2	59.2
Malling Type II.	13	4.7	9.5	13.8	19.0	24.8	33.9	39.0	51.5	56.3	62.3	65.4	68.3	73.3	74.5	74.5
	9	3.0	6.3	11.2	15.0	18.6	25.2	31.7	40.6	44.1	49.2	51.6	57.3	61.0	61.6	61.6
	9	4.7	9.3	12.2	17.0	21.4	28.7	33.9	39.6	41.8	43.7	44.2	46.0	48.5	49.0	49.0
Malling Type IX.	13	1.7	3.5	7.0	10.7	14.8	21.5	25.6	30.8	31.4	32.1	32.2	32.7	32.9	32.9	32.9
	16	3.0	6.3	10.7	15.2	19.1	26.3	31.3	35.4	36.7	37.1	37.2	37.2	37.2	37.2	37.2
	15	6.4	11.2	14.5	19.3	24.2	32.3	38.9	48.9	53.9	59.8	63.3	65.9	68.7	69.0	69.2
Malling Type XII. ..	12	3.3	6.7	9.9	14.3	18.7	26.2	32.8	43.3	47.4	49.6	54.5	56.2	57.5	57.7	57.7
	10	1.8	3.8	6.1	9.7	12.9	19.3	26.1	35.7	38.9	43.6	46.3	48.9	52.4	53.0	53.0

† Note that there is nearly a month between this and the previous measurement.

TABLE VI.

Showing the average total shoot growth of eight selected leader shoots of each of three trees of the variety Lane's Prince Albert, growing upon four different rootstocks.

1926. *Variety.*—Lane's Prince Albert.

Measurements in cms.

Stock	Row.	Tree No.	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Sept. 13 †	Sept. 28	Oct. 5
Malling Type I. ..	1	1	10.0	18.5	26.2	36.8	44.4	52.2	64.0	73.7	79.3	85.7	89.1	93.4	97.3	98.9	9.9
	1	4	11.0	18.9	27.5	37.4	44.8	56.6	66.6	76.3	82.7	89.0	93.2	96.6	110.3	112.0	112.0
	1	6	9.5	18.2	25.6	35.7	44.7	56.5	68.4	78.2	84.1	87.2	89.7	91.0	92.0	92.0	92.0
Malling Type II. ..	2	7	7.5	15.5	23.1	33.2	40.9	50.7	59.6	69.0	73.6	77.8	80.0	81.2	82.2	82.2	82.2
	2	5	7.6	15.3	23.0	32.8	40.9	51.1	61.9	73.0	78.7	84.4	87.5	91.4	97.3	97.3	97.3
	2	3	9.3	16.8	23.4	33.3	39.3	49.7	59.2	70.0	76.8	83.2	87.2	93.2	105.5	107.5	107.5
Malling Type IX. ..	8	2	7.0	13.7	18.2	25.5	30.3	38.2	42.7	50.3	51.8	54.8	56.5	57.3	59.2	59.2	59.2
	8	3	6.9	13.5	17.8	24.9	30.0	37.0	41.7	46.9	50.0	52.4	53.3	53.5	53.5	53.5	53.5
	8	6	4.9	9.5	11.9	15.7	17.9	23.0	24.5	29.7	32.0	35.5	37.0	37.4	38.0	38.0	38.0
Malling Type B. ..	10	8	7.3	15.3	22.2	31.2	39.5	51.3	60.3	70.1	72.3	76.8	78.2	79.8	81.2	81.2	81.2
	10	6	8.7	16.4	23.3	32.5	40.4	51.2	59.7	69.4	72.6	75.1	75.8	76.3	78.2	78.2	78.9
	10	11	7.2	14.5	21.6	30.8	38.8	50.2	59.3	69.8	75.0	81.0	84.6	88.4	92.0	92.0	93.3

† Note that there is nearly a month between this and the previous measurement.

Table VII.

Showing the average total shoot growth of eight shoots of each of three trees of the variety Bramley's Seedling growing upon four different rootstocks.

1926. *Variety.*—Bramley's Seedling. Measurements in cms.

Stock.	Tree No.	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Sept. 13 †	Sept. 28	Oct. 5
Malling Type I. ..	18	6.0	11.2	16.5	21.1	26.5	33.1	40.5	48.0	52.7	57.6	60.1	64.3	72.4	74.1	74.1
	20	5.9	10.8	15.2	19.8	24.7	32.7	39.2	47.7	52.2	57.7	61.0	65.2	73.8	75.6	75.0
	22	7.0	12.0	17.5	23.3	27.9	36.5	43.6	53.4	58.8	65.0	68.0	75.0	84.3	86.8	87.0
Malling Type II. ..	18	6.8	11.9	17.0	21.6	28.0	35.9	42.9	46.5	55.5	62.1	66.3	70.9	83.3	87.1	89.3
	20	7.9	13.8	18.7	24.0	29.9	38.2	44.3	52.7	58.5	62.5	65.5	69.5	78.2	80.7	81.0
	22	8.7	13.9	13.9	28.9	29.6	37.6	44.5	53.8	57.1	64.1	67.7	71.8	79.1	80.4	80.5
Malling Type IX. ..	19	7.5	13.5	17.9	24.0	28.9	35.7	40.1	47.3	51.2	55.4	57.4	59.6	61.3	61.3	61.3
	20	8.2	13.7	17.5	22.7	27.1	34.5	37.9	43.7	45.5	48.4	49.9	51.1	51.2	51.2	51.2
	23*	7.3	12.9	17.5	22.2	26.1	34.7	40.3	48.3	52.7	57.0	59.5	62.3	66.6	67.0	67.0*
Malling Type XII.	23	6.0	13.3	18.3	23.1	29.0	37.9	44.9	54.4	57.9	63.1	64.5	68.4	75.3	76.9	77.1
	21	6.2	11.4	16.5	22.5	28.3	37.4	43.8	52.8	56.5	60.5	62.3	64.2	69.2	70.0	70.2
	18	6.2	11.0	15.1	21.7	27.9	37.3	44.0	53.4	57.6	63.5	67.0	72.2	79.3	82.0	82.7

* This tree has been found upon a stock which is not a true Malling type IX.

† Note that there is almost a month's interval between this and the previous measurement.

TABLE VIII.

Showing the average total shoot growth of twenty-four leader shoots of three varieties growing upon four rootstocks.

1926. Measurements in cms.

Variety and Stock.	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Sept. 13 †	Sept. 28	Oct. 5
LANE'S PRINCE ALBERT.															
Malling Type I. ..	10.2	18.5	26.4	36.6	44.6	55.1	66.3	76.1	82.0	87.3	90.7	93.7	99.9	101.0	101.3
Malling Type II. ..	8.1	15.8	23.1	33.1	40.4	50.5	60.2	70.7	76.4	81.8	84.9	88.6	95.0	95.7	95.7
Malling Type IX. ..	6.8	12.2	15.6	22.1	26.1	31.8	36.3	42.3	41.6	47.5	48.9	49.5	50.2	50.2	50.2
Malling Type B. ..	7.7	15.4	*3.3	31.5	39.6	50.9	59.8	69.8	73.3	77.6	79.5	81.5	83.8	84.0	84.1
WORCESTER PEARMAIN.															
Malling Type I. ..	1.9	4.7	7.2	11.8	15.9	23.1	29.4	37.7	42.9	46.9	50.2	53.6	59.4	61.1	61.8
Malling Type II. ..	3.0	6.8	10.5	14.7	19.1	27.0	33.1	42.9	47.2	32.6	55.8	59.5	64.0	65.1	65.1
Malling Type IX. ..	3.1	6.3	9.9	14.3	18.4	25.5	30.2	35.2	36.6	37.6	37.8	37.9	38.6	39.5	39.7
Malling Type XII. ..	3.8	7.2	10.2	14.4	18.6	26.1	32.6	42.6	46.7	51.0	54.7	57.0	59.5	59.9	60.0
BRAMLEY'S SEEDLING.															
Malling Type I. ..	6.2	11.3	16.4	21.0	26.4	34.1	41.1	47.3	54.6	60.1	63.0	68.2	76.8	78.8	79.0
Malling Type II. ..	7.8	13.2	18.2	24.8	29.1	37.2	43.9	51.3	57.0	62.9	66.5	70.7	80.2	82.7	83.6
Malling Type IX. ..	7.6	13.3	17.6	22.9	27.3	34.9	39.4	46.4	49.8	53.6	55.6	57.7	59.7	59.8	*59.8
Malling Type XII. ..	6.1	11.9	16.6	22.4	28.4	37.5	44.2	53.5	57.3	62.3	64.6	68.2	74.6	76.3	76.6

* Includes one tree upon a rogue stock (see Table 7).

† Note that there is almost a month's interval between this and the previous measurement.

Table IX.

Showing the average weekly growth increment of twenty-four leader shoots of each of three varieties growing upon four different rootstocks.

1926. Measurements in cms.

Variety and Stock.	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Sept. 13 †	Sept. 28	Oct. 5
LANE'S PRINCE ALBERT.															
Malling Type I.	—	8.3	7.9	10.2	8.0	10.5	11.2	9.8	5.9	5.3	3.4	3.0	6.2	1.1	0.3
Malling Type II.	—	7.7	7.3	10.0	7.3	10.1	9.7	10.5	5.7	5.4	3.1	3.7	6.4	0.7	—
Malling Type IX.	—	5.4	3.4	6.5	4.0	5.7	4.5	6.0	2.3	2.9	1.4	1.1	0.7	—	—
Malling Type B.	—	7.7	7.9	8.2	8.1	11.3	8.9	10.0	4.5	4.3	1.9	2.0	2.3	0.2	0.1
WORCESTER PEARMAIN.															
Malling Type I.	—	2.8	2.5	4.6	4.1	8.2	6.3	8.3	5.2	4.0	3.3	3.4	5.8	1.7	0.7
Malling Type II.	—	3.8	3.7	4.2	4.4	7.9	6.1	9.8	4.3	5.4	3.2	3.7	4.5	1.1	—
Malling Type IX.	—	3.2	3.6	4.4	4.1	7.1	4.7	5.0	1.4	1.0	0.2	0.1	1.3	0.9	0.2
Malling Type XII.	—	3.4	3.0	4.2	4.2	7.5	6.5	10.0	4.1	4.3	3.7	2.3	2.5	0.4	0.1
BRAMLEY'S SEEDLING.															
Malling Type I.	—	5.1	5.1	4.6	5.4	7.7	7.0	6.2	7.3	5.5	2.9	5.2	8.6	2.0	0.2
Malling Type II.	—	5.4	5.0	6.6	4.3	8.1	6.7	7.4	5.7	5.9	3.6	4.2	9.5	2.5	0.9
Malling Type IX.	—	5.7	4.3	5.3	4.4	7.6	4.5	7.0	3.4	3.8	2.0	2.1	2.0	*2.1	—
Malling Type XII.	—	5.8	4.7	5.8	6.0	9.1	6.7	9.3	3.8	5.0	2.3	3.6	6.4	1.7	0.3

* Includes one tree upon a rogue stock (see Table 7.

† Note that there is almost a month's interval between this and the previous measurement.

TABLE X.

Showing the total number of blossom clusters opening upon the three selected trees upon each of four rootstocks measured in 1926.

Rootstock.	Year.	Bramley.	Worcester.	Lane's.	Bramley.	Worcester.	Lane's.
					Proportionate tree size calculated upon total shoot growth since planting.		
Malling Type I.	1923	—	44	2			
	1924	—	10	—			
	1925	23	278	388	$3\frac{1}{3}$	$3\frac{1}{4}$	6
	1926	61	119	389			
	1927	174	518	931			
Malling Type II.	1923	—	20	6			
	1924	—	21	17	$3\frac{1}{3}$	$3\frac{1}{2}$	5
	1925	52	190	264			
	1926	62	111	672			
	1927	182	441	914			
Malling Type IX.	1923	*5	58	8			
	1924	3	149	88	1	1	1
	1925	80	328	440			
	1926	80	313	303			
	1927	240	668	468			
No. of Blossom Clusters calculated upon tree of same average size as upon Malling Type II.		**720**	**2,004**	**2,340**			
Malling Type XII.	1923	—	3	—			
	1924	—	4	—			
	1925	4	324	†71	$3\frac{3}{8}$	3	†3
	1926	19	283	128			
	1927	111	681	201			

* One tree upon a stock which is not true to type. (See Table 7.)

† These trees are worked upon Malling B, a layered crab stock.

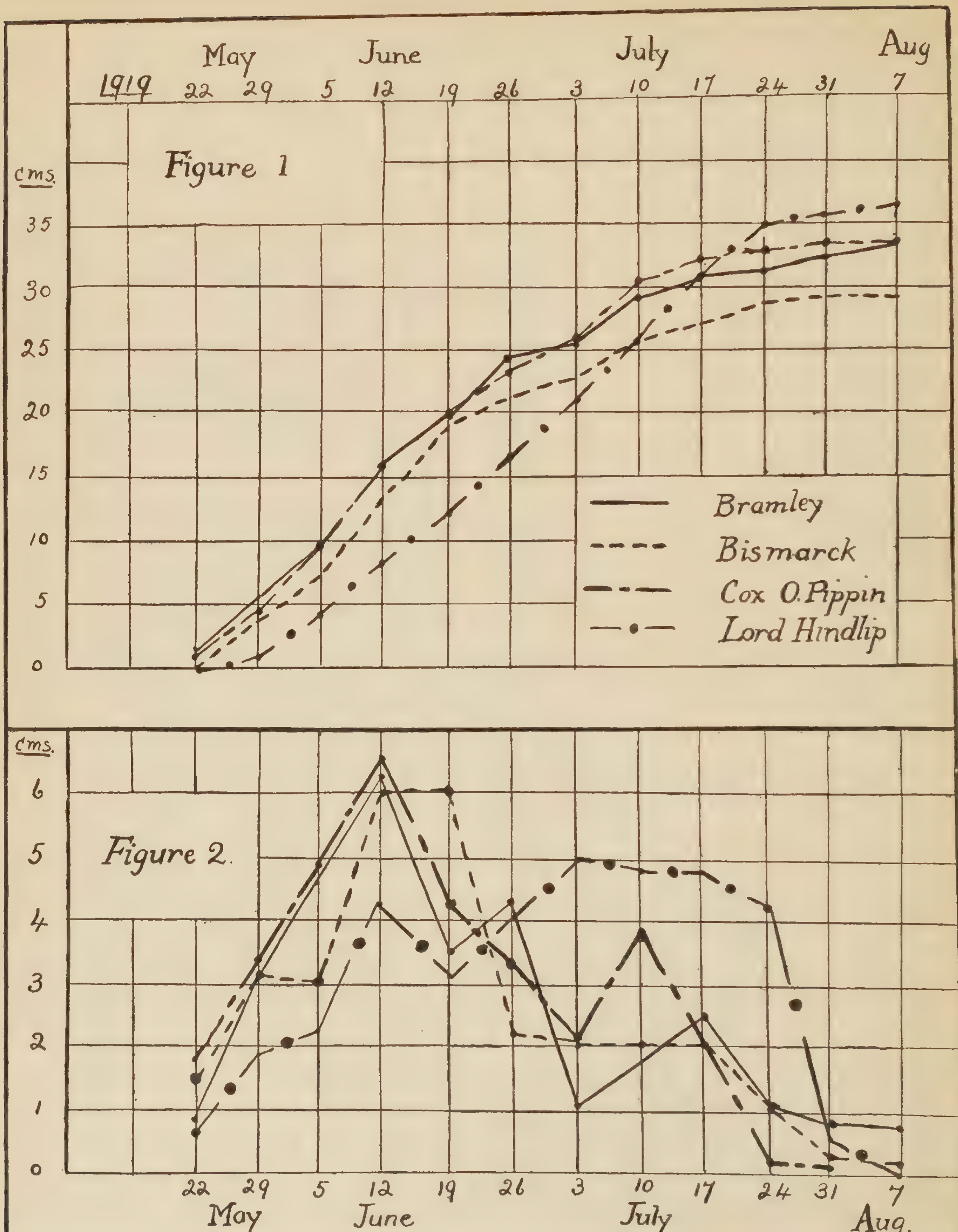
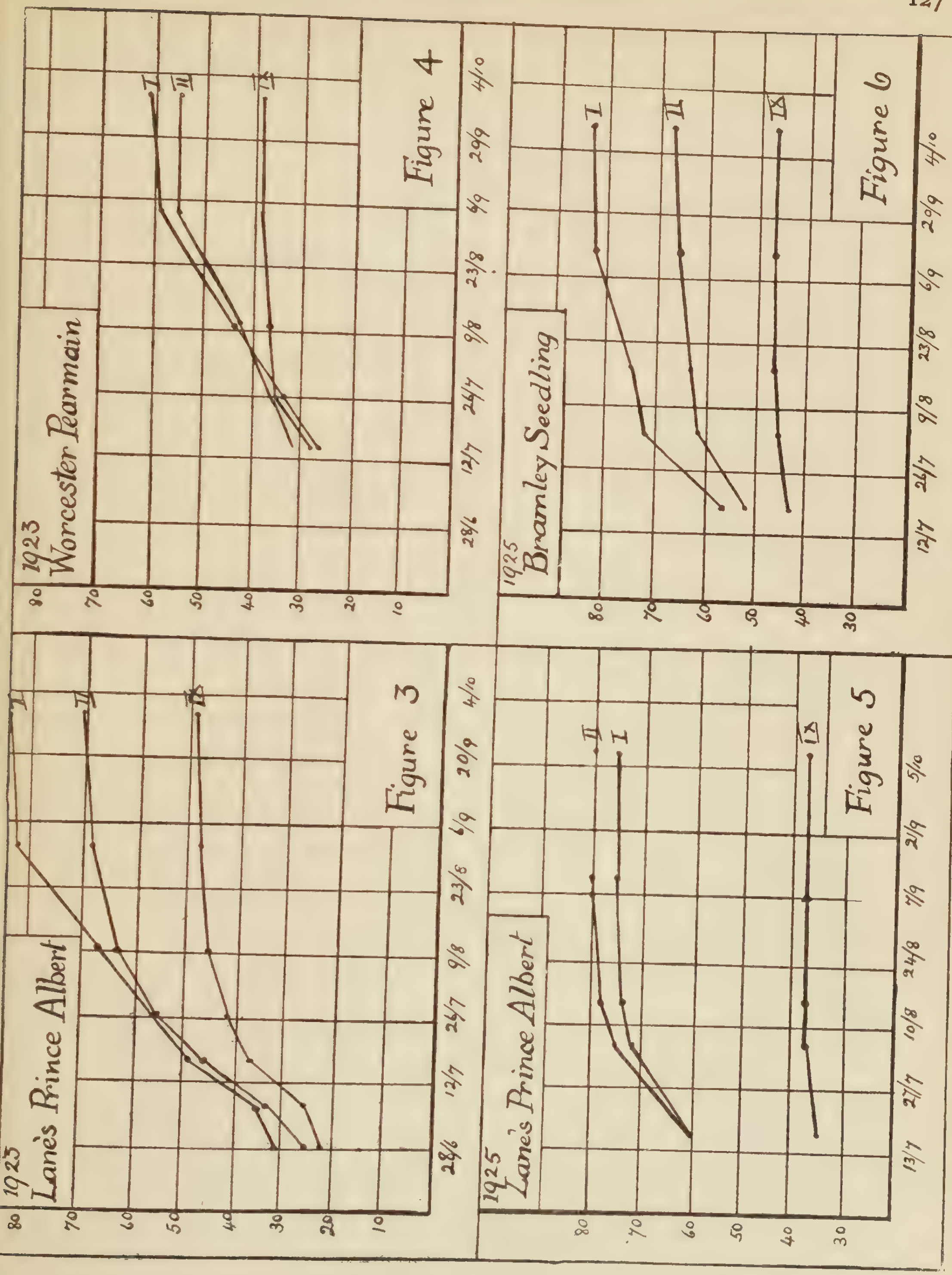
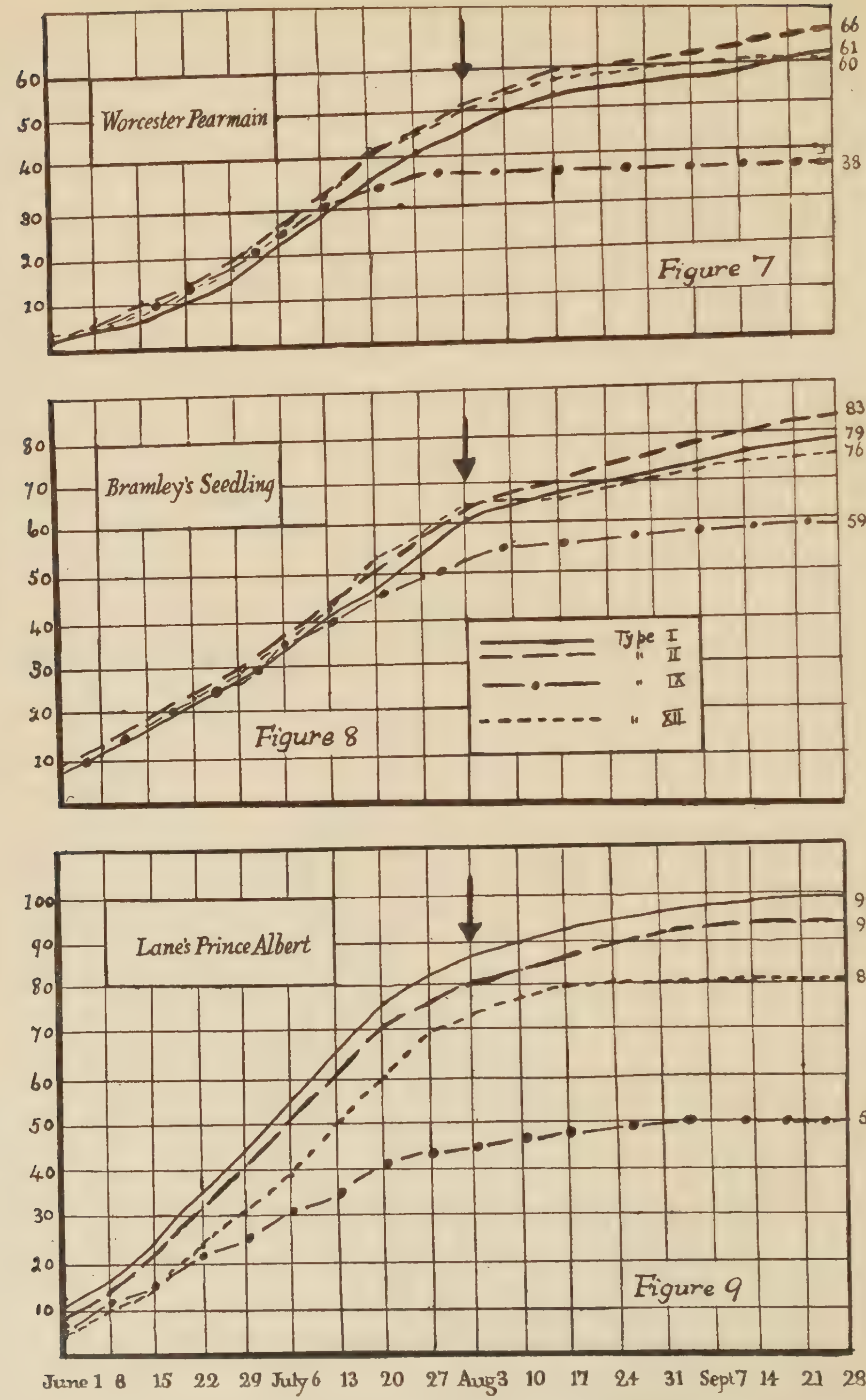


Fig. 1.—Total average shoot growth (10 leader shoots) of four varieties of apple growing upon a uniform rootstock. (Malling Type I.)

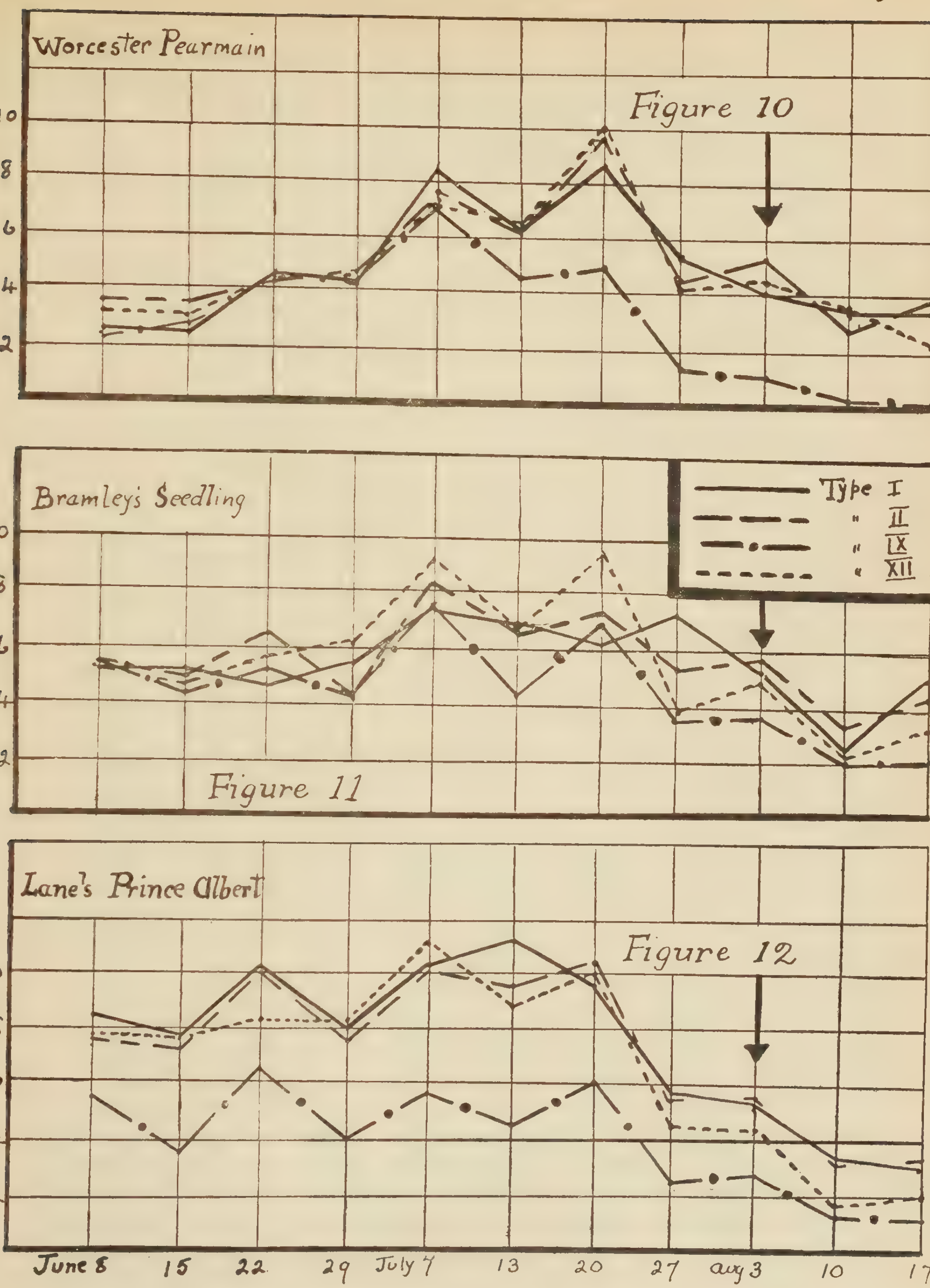
Fig. 2.—Weekly average shoot growth of same four varieties as Fig. 1. Note that although growing upon a uniform rootstock these varieties exhibit a marked individuality in their growth curves. This is reflected in their characteristic fruiting habits.



Figs. 3, 4, 5 and 6.—Total average shoot growth of three varieties upon three vegetatively propagated rootstocks. Measurements for Figs. 3 and 4 taken in 1923, those for Figs. 5 and 6 taken in 1925. Measurements in cms.



Figs. 7, 8 and 9.—Total average shoot growth of twenty-four selected "leader" shoots of each of three varieties growing upon four different rootstocks. Measurements in cms., 1926.



Figs. 10, 11 and 12.—Weekly average shoot growth of twenty-four selected "leader" shoots of three varieties growing upon four rootstocks. Measurements in cms. 1926. Note the variety characteristic growth curves and the effect of rootstock influence.

(*Received* 10/2/28.)

THE EFFECTS OF MANURIAL TREATMENTS ON THE CHEMICAL COMPOSITION OF GOOSEBERRY BUSHES.

I.

EFFECTS ON DRY MATTER, ASH AND ASH CONSTITUENTS OF LEAVES AND STEMS OF TERMINAL SHOOTS AND OF FRUITS; AND ON TOTAL NITROGEN OF FRUITS.

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In a previous number of this Journal, (1) an account was given of a manurial experiment on gooseberry bushes which has been in progress on one of the plots at this Station since the spring of 1921. Data were presented in the paper which showed very clearly that significant results had been produced on the growth, foliage characters and fruiting of the bushes by the action of potassic manures, whilst no specific effects due to the action of nitrogenous or phosphatic manures had been detected. It was also evident that certain differences in the growth of the bushes over the area could be attributed to variations in soil conditions which were known to occur and, whilst potassium appeared to be the limiting factor to the successful growth of gooseberry bushes over the greater proportion of the area, the need for potash manuring was not equally great on the various plots of the area. The manurial treatments in the experiment are given in duplicate—to Series A. and B.—the soil over the area on which the plots in Series A. are located being definitely heavier than that occupied by the Series B. plots, and the results from potash manuring, whilst relatively small on certain areas in Series A., are very marked in Series B.

In view of the very definite results which have been obtained in this experiment, it has been considered desirable to initiate a series of chemical investigations on the bushes with the object of determining to what extent the chemical composition of these has been affected by the treatments. During the summer of 1927, samples of leaves, shoots and berries were taken for analysis and determinations made on these of dry matter, total nitrogen, ash content and ash constituents. The present paper records the results of this investigation. The salient feature which has emerged from the work is that the deficiency of potassium which is so clearly marked in the growth, foliage and fruit characters of the bushes on Plots 8, 9 and 16 where the plants do not receive any potash

manures on the lighter soils, and to a less extent on Plot 1 where the plants receive no manure on the heavier soil, is reflected in the composition of the portions of the plants which have been subjected to analysis.

The results have a practical interest in that they indicate that the analysis of certain portions of the plant may be of use in diagnosing the requirements of fruit trees for potassium.

Since the details of the soil of the plots, the lay-out of the plots, the manurial treatments, and the growth features and cropping of the bushes, etc., have all been previously presented and discussed at length, these are not given in the present account but in order to appreciate the full significance of the results here recorded the previous communication should be consulted.

MATERIALS AND METHODS.*

Leaves and Stems.

The material from which the leaf and stem samples were obtained consisted of terminal shoots of the current season's growth, each shoot comprising the whole of the growth made by the particular shoot during the season.

The shoots from each plot were taken from bushes exhibiting typical growth characters for the plot, and care was taken that each sample consisted of shoots from several bushes and that abnormal material was not included.

The samples were taken from Plots 1 and 8 in Series A. and from all the Plots—9 to 16—in Series B., with the exception of Plot 13. The reason for not taking more samples from Series A. was that it was only possible to deal with a limited number in the laboratory and the growth features resulting from the manurial treatments are more regular in Series B. where the soil variations are not so marked as in Series A.

The whole of the material was collected from the plots during the afternoon of June 28th. The weather at the time was fine, the sun shining brightly and the atmosphere being dry and warm. During the previous week or two, the weather had been wet, following a long drought. The foliage at the time was fresh green in colour and of healthy appearance on all plots with the exception of Plots 1, 8, 9 and 16, where there was much marginal leaf scorch and some purple tinting in evidence. Leaf scorch was especially severe on Plots 8, 9 and 16, in which cases the leaves on the shoots taken for analysis usually exhibited much dead tissue around the margins.

The shoots from all plots generally showed signs of ripening at the basal ends but were usually soft and of unripened appearance near the terminals.

The crop had been picked from the bushes about one week previous to the taking of the samples.

* The chemical determinations entailed in this investigation were carried out under the writer's direction by Mr. A. N. Dunsby, B.Sc., A.I.C.

All the samples were collected into metal containers and conveyed without delay to the laboratory where they were prepared for the various determinations the same day.

The samples for analysis were prepared from the shoots as "leaves" and "stems" in the following way:

A suitable weight of shoots was selected from the bulk sample in each case and the laminæ of the leaves were cut off from the shoots with a pair of scissors into large tared beakers. The shoots were cut at the basal ends at the points to which the most basally situated leaves had been attached and the portions of the shoots above these points used for analysis. In this way the portions of stems analysed were those along which the leaves used had been borne and in every case consisted practically of the whole of the current season's growth.

The stems were further cut into small sections and transferred to tared beakers for analytical determinations.

The leaves as analysed thus consisted only of laminæ whilst the "stems" included the stems, petioles and spines.

The weights of the samples of leaves and stems used in each case are given in Tables I. and II.

The determinations carried out in each case were dry weights (steam oven), total ash and ash constituents as shown in the Tables.

Berries.

Samples of berries were analysed from all plots in Series A. and B. They were taken from the bulk crops from the plots and were picked under dry conditions on June 20th.

The samples were taken on June 21st and as it was not possible to deal with them at once they were placed in the cold store where they were kept until June 29th. On this latter date they were removed to a cool cellar and were brought to the laboratory on the following day. The task of preparing the samples for analysis proved to be much longer than was anticipated and extended over the period June 30th to July 5th, during which time the samples were kept in a cool laboratory in "chip" baskets covered with sheets of newspaper.

The method adopted in the preparation of the samples was as follows.

A suitable bulk of berries was selected from each sample. The berries were "topped" and "tailed" and then passed quickly two or three times through a mincing machine. The pulp obtained in this way was transferred in small quantities to a mortar and thoroughly ground and afterwards the whole was well mixed in a large beaker.

Separate portions were weighed out for total nitrogen, dry matter and ash determinations. In the dry matter determinations, the samples were subjected to a preliminary drying on a water bath at 70° C. and were finally dried to

constant weight in a constant temperature oven at 70° C. The results obtained by this method are empirical, but it has not been found possible to obtain a better method, the use of higher temperatures resulting in much charring due to the high degree of acidity in the material.

It was thought that the use of the mincing machine would lead to high results for iron in the ash and as this was found to be the case all results have been calculated on an iron-free basis. Since the actual percentage of iron in the ash is very small, the results on this basis will not differ materially from those which would have been obtained had the amount of iron in the berries been included.

RESULTS.

Leaves.

The results obtained on the samples of leaves are presented in Tables I. a and b. In Table I. b the values obtained for the more important ash constituents are shown as percentages of the fresh weights.

The main points brought out in the results in Tables I. a and b are as follows :

The results for dry weight are somewhat irregular though the values for the plots showing marked potassium starvation—Plots 8, 9 and 16—are definitely on the high side. On the other hand, the result for Plot 1 where the foliage at the time of sampling was showing a fair amount of leaf scorch, is the lowest in the table. The reason for this low value is not clear at the present time.

The values for ash in dry weight also show some irregularity and no definite point emerges though it should be noted that the values for Plots 1, 8, 9 and 16 are on the high side rather than on the low which is in contrast with the results presented in Tables II. and III.*

In considering the ash constituents, it is not proposed to discuss in detail the results obtained for silica, oxide of iron or alumina, though in passing it may be mentioned that the percentage of silica is relatively high in the samples from Plots 1, 8, 9 and 16, the potassium deficient plots.

The results for the major ash constituents are very interesting and show some marked relationships to the manurial treatments. In discussing the main points, the plots can be placed conveniently into two groups, those where potash is not applied—Plots 1, 8, 9 and 16—and those where potash is included in the manurial treatment—Plots 10, 11, 12, 14 and 15. In the case of Plot 10, the only potash given is contained in the dung which is applied.

Examination of the results for the bases CaO, MgO, K_2O, and Na_2O according to the above groups shows the following features :

* In numerous unpublished data, it has been found almost invariably by the writer that values for ash in dry weight in leaves in cases of potassium deficiency are significantly low.

TABLE I.

LEAVES.

a.—*Showing Manurial Treatments; Dry Weight as Percentage Fresh Weight; Ash as Percentage Dry Weight; Ash Constituents as Percentages of Ash.*

Series.	Plot No.	Manurial Treatment.	Fresh Weight taken (grms.).	Dry Weight % of Fresh Weight.	Ash % of Dry Weight.	Ash Constituents as Percentages of Ash.							
						SiO_2	Fe_2O_3	Al_2O_3	CaO	Mgo	K_2O	Na_2O	P_2O_5
A.	1	No Manure.	64.66	34.72	8.96	1.44	0.38	0.10	38.48	6.86	11.81	6.17	8.90
,,	8	N. P.	61.67	40.25	8.40	1.76	0.37	0.16	37.82	6.77	10.04	5.82	8.80
B.	9	No Manure.	56.74	38.20	8.04	1.91	0.53	0.30	36.80	7.20	10.89	8.08	7.88
,,	10	Dung.	79.20	36.20	8.64	1.42	0.32	0.27	29.08	5.11	23.28	3.97	6.01
,,	11	N. + P. organic, K.	68.71	36.30	8.61	0.98	0.37	0.12	29.26	5.41	22.20	4.32	7.03
,,	12	N. + P. inorganic, K.	90.65	37.20	7.78	1.07	0.31	0.19	30.49	5.22	22.78	3.60	7.61
,,	14	P. K.	66.59	35.43	7.65	1.50	0.42	0.10	29.84	5.17	24.10	3.19	8.29
,,	15	N. K.	67.25	35.10	7.70	1.69	0.45	0.12	29.61	5.30	24.49	3.53	8.08
,,	16	N. P.	69.50	38.80	8.39	3.19	0.21	—	39.09	7.46	7.69	5.43	9.86

b.—*Showing Chief Ash Constituents as Percentages of Fresh Weights.*

Plot Nos.	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %
1	1.1970	0.2134	0.3675	0.1920	0.2769
8	1.2780	0.2289	0.3394	0.1967	0.3002
9	1.1310	0.2212	0.3349	0.2482	0.2420
10	0.9048	0.1590	0.7244	0.1235	0.1870
11	0.9145	0.1690	0.6939	0.1350	0.2198
12	0.8824	0.1511	0.6592	0.1042	0.2203
14	0.8089	0.1402	0.6533	0.0865	0.2248
15	0.8074	0.1820	0.6679	0.0963	0.2204
16	1.273	0.2429	0.2503	0.1768	0.3210

The values for CaO, MgO and Na_2O are high for Plots 1, 8, 9 and 16 in comparison with those for Plots 10, 11, 12, 14 and 15, the differences for each base being extremely well marked.

The results for K_2O on the plots receiving no potash range from approximately 7.8 per cent. to 11.8 per cent. whilst the values on the plots comprising the group receiving potash range from 22.2 per cent. to 24.5 per cent. K_2O.

There is also a point of interest in the results for P_2O_5 which is that the values for the " no potash " plots are relatively high when compared with those for the plots receiving potash, and this in spite of the fact that Plots 1 and 9, being " no manure " plots, have not received any phosphorus during the course of the experiment. The value for P_2O_5 on Plot 15 does not appear to show any marked phosphorus starvation due to the treatment given and indeed the phosphorus content of the material appears to have been affected more by the omission or addition of potassium in the manuring than by the omission or addition of phosphorus.

The low content of phosphorus on Plot 10 where dung only has been applied should be noted.

With regard to the results presented in Table I. b it is only necessary to remark that these bring out the same relationships as are shown in I. a thus showing that the quantities and proportions of inorganic constituents in the leaves have been substantially affected by the manurial treatments.

Stems.

The results for stems are given in Tables II. a and b in the same manner as for the leaves in Tables I. a and b.

TABLE II.

STEMS.

a.—*Showing Manurial Treatments; Dry Weight as Percentage Fresh Weight; Ash as Percentage Dry Weight; Ash Constituents as Percentages of Ash.*

Series.	Plot No.	Manurial Treatment.	Fresh Weight taken (grms.)	Dry Weight % of Fresh Weight.	Ash % of Dry Weight.	Ash Constituents as Percentages of Ash.							
						SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5
A.	1	No Manure.	31.31	39.83	4.54	—	0.56	—	34.46	3.84	12.57	6.78	13.76
,,	8	N. P.	28.37	38.80	4.73	—	0.60	—	33.49	3.51	13.44	7.32	13.93
B.	9	No Manure.	26.29	38.00	4.61	—	0.59	—	34.91	3.78	13.15	6.03	13.52
,,	10	Dung.	39.82	36.00	5.65	—	0.32	—	29.96	3.39	22.55	3.60	9.02
,,	11	N. + P. organic, K.	20.02	36.07	5.57	—	0.45	—	33.69	3.76	20.80	3.82	11.61
,,	12	N. + P. inorganic, K.	50.98	34.40	5.23	—	0.38	0.19	32.44	3.26	24.34	2.93	9.60
,,	14	P. K.	36.99	34.30	5.25	—	0.28	0.05	31.23	3.21	21.50	3.74	9.09
,,	15	N. K.	38.32	32.70	5.40	—	0.28	0.04	29.70	3.09	20.54	5.13	8.40
,,	16	N. P.	30.88	36.00	4.80	—	0.60	0.36	36.27	3.55	12.64	5.71	14.47

b.—*Showing Chief Ash Constituents as Percentages of Fresh Weights.*

Plot Nos.	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %
1	0.6233	0.0694	0.2273	0.1226	0.2488
8	0.6132	0.0644	0.2467	0.1344	0.2557
9	0.6115	0.0662	0.2303	0.1056	0.2368
10	0.6080	0.0689	0.4586	0.0732	0.1834
11	0.6753	0.0755	0.4179	0.0768	0.2333
12	0.5835	0.0587	0.3790	0.0527	0.1728
14	0.5624	0.0578	0.3872	0.0674	0.1637
15	0.5244	0.0546	0.3626	0.0906	0.1484
16	0.6266	0.0613	0.2184	0.0987	0.2500

The results on the stems show many relationships of a similar character to those exhibited by the leaves and, in general, show that the values for the plots receiving "no potash" are quite distinctive from those receiving potash treatment. In the results for dry weight, the values for Plots 1, 8 and 9 are distinctly higher than those for the other plots, whilst that for Plot 16, although not above the values for Plots 10 and 11, is much higher than those for the neighbouring plots. The percentages of ash in the dry weight also show significant differences between the two groups, the values for the potash treated plots being well above those for Plots 1, 8, 9 and 16.

The results for the ash constituents show the same general relationships as are shown by these in the leaves though there are points of difference which are worthy of note. The bases CaO, MgO and Na_2O are all higher for Plots 1, 8, 9 and 16 than for the other plots with the exception of Plot 11 where the results for all the constituents appear to be intermediate between those of the two groups though the K_2O content would place this plot definitely with the potash group.

The differences in K_2O content are extremely well defined, the values for the plots receiving potash ranging from 20.5 per cent. to 24.3 per cent. whilst those for the plots receiving "no potash" fall within the narrow range of 12.6 per cent. to 13.4 per cent.

The results for P_2O_5 show the same marked feature as was observed in the case of the leaves, namely that the values for Plots 1, 8, 9 and 16 are distinctly higher than those for Plots 10, 11, 12, 14 and 15. The value for plot 15, which receives the treatment "phosphorus omitted," is low and that for Plot 10, to which dung is applied, is also on the low side. Here again, greater changes have been

effected in the content of P_2O_5 by the omission or addition of potassium than by the omission or addition of phosphorus in the plot dressings.

In Table II. b, where the values for the major ash constituents are given as percentages of fresh weight, it will be observed that with the exception of the percentages of CaO and MgO in Plot 11 the results fit into the two groups as in Table II. a.

Berries.

Tables III. a and b contain the results obtained on the berries. The results are from the whole of the sixteen plots of the experiment and include determinations of total nitrogen in addition to the other inorganic constituents.

TABLE III.

a.—*Showing Manurial Treatments; Dry Weights as Percentage Fresh Weight; Ash as Percentage Dry Weight; Ash Constituents as Percentages of Ash.*

Series.	Plot No.	Manurial Treatment.	Fresh Weight taken (grms.).	Dry Weights % of Fresh Weight.	Ash less Fe_2O_3 % of Dry Weight.	Ash Constituents as Percentages of "Fe_2O_3 free" ash.				
						CaO	MgO	K_2O	Na_2O	P_2O_5
A.	1	No manure.	300.55	11.75	3.24	7.57	4.33	44.80	4.03	16.96
	2	Dung.	380.50	11.47	3.49	6.74	3.78	48.40	3.03	13.10
	3	N + P. organic, K.	347.15	10.60	4.28	6.68	3.87	48.90	3.01	13.22
	4	N. + P. inorganic, K.	389.41	10.85	3.49	6.44	4.01	47.90	3.54	16.64
	5	N. + P. ½ organic ½ inorganic ;K	421.84	11.02	3.28	7.36	4.13	43.50	4.04	14.86
	6	P. K.	385.32	11.05	3.16	7.81	4.45	44.67	3.44	18.75
	7	N. K.	332.82	10.97	3.56	7.18	3.81	44.84	4.20	15.91
	8	N. P.	424.89	11.07	2.94	8.23	4.63	41.55	7.06	21.00
B.	9	No Manure.	443.23	10.70	3.02	7.92	4.60	41.37	5.53	20.41
	10	Dung.	300.74	10.95	3.83	5.08	3.07	46.30	3.90	15.75
	11	N. + P. organic, K.	404.10	10.85	3.42	6.07	3.84	45.44	3.14	17.38
	12	N.+P. inorganic, K.	464.55	10.77	3.69	5.96	3.60	43.90	4.78	15.82
	13	N.+P. ½ organic ½ inorganic ;K	409.05	10.65	3.64	5.97	3.57	49.00	3.65	17.17
	14	P. K.	332.87	9.75	4.07	6.10	3.63	46.70	3.17	17.01
	15	N. K.	364.62	11.17	3.67	5.50	3.72	48.38	3.69	15.50
	16	N. P.	377.85	11.05	2.80	7.80	4.66	41.56	7.44	22.22

b.—*Showing Total Nitrogen and Chief Ash Constituents as Percentages of Fresh Weights.*

Plot Nos.	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	Total Nitrogen.
1	0.0288	0.0165	0.171	0.0153	0.0646	0.140
2	0.0270	0.0151	0.194	0.0121	0.0524	0.132
3	0.0303	0.0176	0.222	0.0137	0.0476	*0.147
4	0.0244	0.0152	0.181	0.0134	0.0630	0.157
5	0.0266	0.0149	0.157	0.0146	0.0537	0.154
6	0.0273	0.0155	0.156	0.0120	0.0655	0.144
7	0.0280	0.0149	0.175	0.0164	0.0622	0.147
8	0.0268	0.0151	0.135	0.0230	0.0683	*0.177
9	0.0256	0.0148	0.134	0.0179	0.0660	0.170
10	0.0213	0.0129	0.194	0.0164	0.0661	0.168
11	0.0225	0.0143	0.169	0.0117	0.0645	*0.160
12	0.0237	0.0143	0.175	0.0190	0.0629	0.176
13	0.0232	0.0139	0.190	0.0142	0.0666	*0.165
14	0.0242	0.0144	0.185	0.0126	0.0675	0.158
15	0.0225	0.0152	0.198	0.0151	0.0634	*0.178
16	0.0241	0.0144	0.129	0.0230	0.0688	*0.175

* Denotes based on a single determination.

In considering the results in Tables III. a and b, it is necessary to bear in mind that Plots 2 to 7 and 10 to 15 inclusive receive potash in the manurial dressings. Further it should be noted that, although the manurial treatments given in Series B. are duplicates of those in Series A, the results from the similar treatments in the two series have not been identical owing to soil variation. Thus on Plot 1 which receives no manure the bushes have made relatively good growth since planting although the foliage has exhibited fairly marked leaf scorch, especially during the later stages of the experiment. The soil of the plots in Series A. is definitely heavier than that of the plots in Series B. and there is a significant gradient in texture in passing from Plot 1 to Plot 8.

The values for dry matter were obtained by drying to constant weight at 70° C. and for this reason they do not represent true dry weights. It is possibly because of this that the results do not show any significant differences between the potash treated and " no potash " plots. The percentages of ash in the dry matter are significantly lower in Plots 8, 9, and 16 than in the other plots whilst the value for Plot 1 is also lower than those for the neighbouring plots.

Consideration of the data for the bases and P_2O_5 in the ash shows that similar relationships hold for the berries as in the cases of the leaves and stems. The percentages of CaO, MgO and Na_2O are definitely higher in Plots 8, 9 and 16 than in the plots treated with potash whilst the percentages of these bases in Plot 1, although not always higher than those for all these plots, are in all cases significantly higher than those of neighbouring plots. The values obtained for K_2O also show well marked differences between the plots in the two groups. On Plots 8, 9 and 16, the percentages are approximately 41.5 per cent. in each case, being well below those on the other plots, whilst the value for Plot 1, although

not lower than every one of the potash treated plots, is well below those of the adjoining plots.

The results for P_2O_5 show the same feature as in the previous cases, the values for Plots 8, 9 and 16 being well above those for the potash group and that for Plot 1 being higher than those for Plots 2 and 3. The values for Plots 7 and 15 which receive "no phosphorus" treatment are below those of the adjoining plots and possibly reflect the treatment.

Plots 2 and 10, to which dung is given, show relatively low results as in the cases of the leaves and stems.

In Table III. b where the ash constituents are calculated as percentages of the fresh weights, it will be observed that in certain cases the order of values shown in III. a is not retained and the differences between the potash and "no potash" groups of plots are not maintained.

The changes occur in the cases of CaO, MgO and P_2O_5 and are due to the small percentage of ash in the fresh material and the significantly lower proportions of ash in the fresh material from the plots which do not receive the potash dressings.

For these same reasons, the differences for K_2O shown in Table III. a become more pronounced when given on the fresh weight basis in Table III. b.

The results reported for total nitrogen are not very complete since it was only possible to carry out single determinations in certain cases but it has been considered worth while including them since they do appear to give indications in certain directions.

The first point which calls for mention is that the values in Series B. on the lighter soil area are distinctly above those in Series A. where the soil is heavier. The values for Plots 8, 9 and 16 are relatively high and of these Plot 9 does not receive any manurial treatment. On Plot 1, also an unmanured plot, although the result is relatively low in the series, it is above that for Plot 2 which receives dung, these two plots being adjoining plots on the heaviest soil of the area. Plots 4 and 12 receive their nitrogen in the form of nitrate of soda, whereas Plots 3 and 11 are given the same amount of nitrogen in the form of dried blood. It will be seen that in these cases the value for Plot 4 is above that for the adjoining Plot 3 and that for Plot 12 is higher than that for the adjoining Plot 11. These differences possibly indicate the relative efficiencies of these two types of nitrogenous manures as sources of nitrogen. Lastly, Plots 6 and 14 are the "no nitrogen" plots and it is seen in the table that the values in these cases are below those of the plots on either side of them.

Discussion.

From the data obtained over five seasons on the growth and cropping of the bushes considered in this paper, it was concluded that the limiting factor to both

growth and cropping on the plots was potassium. Increases in growth and cropping resulted from annual applications of dung, complete artificials containing nitrogen, phosphorus and potassium and artificials containing nitrogen plus potassium and phosphorus plus potassium. Where no manure was given or where potassium was omitted from the manure, growth and cropping were severely affected and the bushes showed the characteristic symptoms of potassium starvation.

The omission of either nitrogen or phosphorus from the manure did not produce significant effects and no signs of either nitrogen or phosphorus starvation were observed on the plots from which these elements were withheld.

The variable character of the soil resulted in growth and cropping differences ; in Series A. the bushes were able to make relatively good growth where no manure was given but in Series B. where the soil is lighter, bushes receiving this treatment showed severe potassium starvation. The manures affected growth to a much greater extent on the Series B. plots than on those in Series A.

It is a matter of some importance to know in what ways and to what extent the composition of the plant is affected by different manurial treatments and especially so from the viewpoints of treatments with the elements nitrogen, phosphorus and potassium. In cases where any one of these acts as a definite limiting factor to the healthy growth of the plant, since growth is invariably greatly restricted, it might be that the composition will not be greatly altered but that the plant will merely continue to grow to the point when the supply of the limiting element becomes depleted. If this be so, it would not appear profitable to pursue studies on the composition of the plant as an index to its condition or requirements but there is abundant evidence to show that at least for synthesised carbohydrate and nitrogen products the composition of fruit plants is markedly affected by nutritional conditions, especially with relation to nitrogen supply.

In this type of investigation, the points relating to the composition of the plant which require examination are the water content of the tissues, the nature of and relationships between the synthesised products, the ash content and the composition of the ash. It is also important to discover which portion, or portions, of the plant provides the most suitable index for any particular purpose.

In the present instance, the material used consisted of the leaves and stems of the current season's shoots and of the fruits. Of these the stems and fruits are largely utilised as storage organs, whilst the leaves are more concerned with the primary synthetic processes. This being so, it might be reasonably expected that the leaves would furnish information more especially on relationships holding among the various substances during the primary stages of syntheses, whilst the

stems and fruits would show the relationships existing among the elaborated products. The current year's shoots were selected in preference to older material since it seemed likely that these portions of the shoots would reflect the current activities of the plants more accurately than would those from older growths.

The results reported in Tables I. to III. show that the different manurial treatments have produced significant effects in all three portions of the plants, especially on the ash constituents.

The large differences exhibited reflect the treatments of the plots with respect to potash applications and show very clearly that not only has potassium deficiency resulted in decreased growth but that the potassium starved plants differ widely in composition from those which have received the element in their diets.

In the case of percentage dry weights, these are significantly higher where potash has not been applied in the leaves (Plot 1 is possibly an exception), and in the stems. This is not shown in the berries but this may be due to the weakness of the method of determination employed. In confirmation of these results for the stems, it may be stated that similar results have been obtained by the writer on stems of apples (data unpublished) and it appears exceedingly probable that physiological dryness of tissues is a characteristic of potassium starved fruit plants.

The results for ash in the dry weights are not in the same direction in each case. In the leaves* there is possibly a tendency for the ash to be on the high side in the leaves of the potassium deficient bushes, whilst in the stems and fruits it is significantly lower in each case. Other results which the writer has obtained on apple and plum leaves (data unpublished) have indicated that the ash in the dry matter in cases of potassium deficiency is generally lower than where growth is normal.

The results for the ash constituents all show the same features though to different extents. Where no potassium is given in the manure in the cases of the two unmanured plots—1, 9—and those receiving nitrogen and phosphorus only—8 and 16—the percentages of the bases CaO, MgO and Na_2O are relatively high and the percentages of K_2O are distinctly low. The differences are greatest in the leaves and least in the berries and especially so for CaO and K_2O and it would appear that potassium deficiency will be more readily detected by examination of the leaves or stems than of the fruits.

An extremely interesting point is shown in the results obtained for P_2O_5. This is that, in every case where potassium has not been applied, the percentage of P_2O_5 in the ash is relatively high. The greatest differences are to be found in the stems and the berries which function as storage organs. The high results for phosphorus in the potash deficient material indicate that the problem of

* See footnote, p. 133.

deficiencies is not a simple one since phosphorus is not given to Plots 1, 7, 9 and 15, and whilst low phosphorus is indicated in all materials examined from Plots 7 and 15, the results on Plots 1 and 9, where potassium starvation is in evidence, are distinctly high. It may be that analysis of plant tissues will only furnish evidence of deficiency of an element when the element has become the primary limiting factor to growth.

A further point in the results for P_2O_5 is that in all three cases the values for the plots receiving dung treatment are low.

In sections b of the Tables, where the ash constituents are reported as percentages of the fresh weights, it is seen that, in the cases of the leaves and stems, the actual percentages of CaO, MgO, Na_2O and P_2O_5 in the fresh materials (Plot 11, CaO and MgO excepted) are higher in the samples from the potassium deficient plots than in those from the plots which have been manured with this material. It has already been pointed out that these differences do not hold so consistently in the case of the berries.

The points indicated in the results of the nitrogen determinations on the berries have been referred to previously in discussing Table III. b, and the only two points which perhaps require repeating here are that the "no nitrogen" treatment is indicated by the results on Plots 6 and 14, whilst where nitrogen is not given on Plots 1 and 9, but where potassium appears to be the limiting factor to growth, the results for nitrogen are relatively high. The values for nitrogen on Plots 8 and 16 are also definitely high.

These findings are thus similar to those reported in the case of P_2O_5 on the plots receiving "no phosphorus."

It is of interest to compare the percentages of dry weight in fresh materials, ash in dry matter and of ash constituents in ash in the leaves, stems and berries.

The dry weight in fresh material is slightly higher in the leaves than in the stems and the percentages in these are much higher than in the berries. The ash in dry matter is also highest in the leaves and again is lowest in the berries. Of the major ash constituents, as percentages in the ash, CaO is similar in proportion in leaves and stems though it rises to higher values in the former than in the latter in the potassium deficient cases. The values for the berries are only about one-fifth of those in the leaves and stems. MgO shows the highest values in the leaves but is never high, those in the stems and berries being similar. The percentages of K_2O are highest in the berries which is a point of difference from CaO and MgO. The amounts in the leaves and stems are similar where the element is not deficient. The values for Na_2O are never high and do not show large differences in the three cases. The percentages of P_2O_5, like those for K_2O, are distinctly highest in the fruits. They are definitely lower in the leaves than in the stems.

The different proportions of the ash constituents in the fresh weights are shown in sections b of the Tables and show a gradation in amounts downwards from leaves to stems to fruits, especially so in the case of CaO.

CONCLUSIONS.

The following conclusions relating to the effects of the manurial treatments given in the experiment under consideration on the composition of the leaves and stems of terminal shoots and on the berries from the treated bushes are drawn.

1. Where potassium is not applied in the manures given to the plots, the deficiency of the element is reflected in the percentages of K_2O in the ash and fresh weight of the leaves, stems and berries. The greatest differences are shown in the leaves and stems, those in the berries being of a much smaller order.
2. Deficiency in potassium is associated with higher dry matter in the leaves and stems ; with lower percentages of ash in the dry matter in the stems and berries ; and with higher percentages of CaO, MgO, Na_2O and P_2O_5 in the ash of leaves, stems and berries.
3. Fluctuations in the percentage of CaO in the ash associated with differences in K_2O are greatest in the leaves and smallest in the berries ; conversely, fluctuations in P_2O_5 associated with differences in K_2O are smallest in the leaves and greatest in the berries.
4. Potassium deficiency tends to mask low supplies of nitrogen or phosphorus when an attempt is made to determine supplies of these latter by analysing leaves, stems or berries in the case of phosphorus or berries only in the case of nitrogen.

SUMMARY.

Leaves, stems and berries taken from gooseberry bushes which had been growing under various manurial treatments for six seasons were analysed for dry matter, ash content and ash constituents with a view to determining the extent to which the composition of these had been affected by the manurial treatments. The leaves and stems used were taken from current season growths of terminal shoots. Determinations of total nitrogen were also carried out on the berries.

The manurial treatments given include no manure, dung, complete artificials, and complete artificials less nitrogen, phosphorus and potassium respectively.

The treatments " no manure " and " potassium omitted " have resulted in severe restriction in growth and cropping and in severe leaf scorch due to potassium starvation.

The analytical results show the following features :

1. The deficiency of potassium, where this element is not applied, is clearly shown in the composition of the ash of leaves, stems and berries, especially in the two former.
2. Low percentages of K_2O in the ash are accompanied by relatively high values for CaO, MgO, Na_2O and P_2O_5.
3. In the stems and berries, the potassium deficient plants show low percentages of ash in dry matter.
4. The percentages of dry matter in the fresh material are high in the leaves and stems where potassium is deficient.
5. Where phosphorus is not applied the treatment is reflected in the ash of the leaves, stems and berries when potassium is given, but when the latter element is deficient, as on the "no manure" plots, the phosphorus content of the ash in all cases is high. Similar results to the above were obtained for total nitrogen in the fresh weight in the berries, potassium deficiency masking low nitrogen supply.
6. Material from the plots treated with dung showed relatively low amounts of P_2O_5 in the ash in all cases.

It is concluded from the investigation that the deficiency of potassium which is apparent in the growth and cropping of the bushes where this element is not given is clearly reflected in the K_2O contents of the ash and the fresh material of the leaves and stems of terminal shoots and of the berries. The differences produced in K_2O content are greater in the leaves and stems than in the berries.

REFERENCE.

1. Wallace, T. *J. Pomol. and Hort. Science*, Vol. VI, pp. 184-197. Field Experiment on the Manuring of Gooseberry Bushes. (1927.)

(*Received* 30/1/28.

A REPORT ON FIELD TRIALS WITH 3:5-DINITRO-O-CRESOL AND ITS SODIUM SALT FOR WINTER SPRAYING.

EDITED BY C. T. GIMINGHAM AND F. TATTERSFIELD.

It has already been shown by quantitative experiments under laboratory conditions and on a small scale in the field* that dinitro-*o*-cresol and its salts possess a high toxicity to the eggs of aphides, Psyllæ and certain moths, and that, when suitably prepared as spray fluids, these substances can be applied to fruit trees during the dormant period without injury. It therefore appeared advisable to make experiments on a larger scale and in several different parts of the country, in order to test the efficiency of dinitro-cresol under differing conditions and to obtain information with regard to any difficulties which might be encountered in using it in the field.

At the request of Mr. J. C. F. Fryer, Director of the Plant Pathological Laboratory of the Ministry of Agriculture and Fisheries, the Entomological Advisors of several provinces kindly undertook to carry out field trials during the winter 1926-27; and the results of these series of experiments are given in the form of separate reports from each of the experimenters.

It was decided to use both dinitro-cresol itself and the sodium salt, and the two washes were prepared and sent out to each centre in the form of concentrated stock solutions. Dinitro-cresol is only slightly soluble in water and it is necessary to use an organic solvent. A proprietary emulsified disinfectant was found suitable for this purpose and the stock solution consisted of a 10 per cent. solution of dinitro-cresol in this solvent. The sodium salt is much more soluble in water and is prepared by treatment of dinitro-cresol with a hot concentrated solution of the appropriate amount of sodium carbonate. The stock solution in this case consisted of a 5 per cent. solution of sodium dinitro-cresylate in water and was used with soap to assist spreading and wetting.

The composition of the washes when diluted with water to the specified strength was as follows :—

Wash A contained 0.2 per cent. dinitro-cresol and 2 per cent. solvent. Previous experiments have shown that the solvent at this strength has no toxicity to insect eggs.

Wash B contained the sodium salt of dinitro-cresol equivalent to 0.2 per cent. dinitro-cresol, together with 0.5 per cent. soft soap, the stock solution being first diluted and the soap added afterwards.

* Cf. C. T. Gimingham, A. M. Massee and F. Tattersfield, *Ann. App. Biol.*, 1926, **13**, 446; C. T. Gimingham and F. Tattersfield, *J. Agric. Sci.*, 1927, **17**, 162.

The two washes, A and B, were compared at each centre with one or more proprietary tar distillate spray-fluids. Details of each set of experiments are given in the separate accounts which follow.

REPORT ON SPRAYING TRIALS WITH DI-NITRO-CRESOL, CARRIED OUT AT THE SEALE-HAYNE AGRICULTURAL COLLEGE, NEWTON ABBOT, DEVON, FEBRUARY, 1927.

The trial consisted of a comparison between Washes A and B, supplied by Rothamsted Experimental Station, and a proprietary tar distillate wash. Adequate unsprayed control trees were left.

The orchard utilised for the trial was composed entirely of bush trees, varying from five to ten years of age and inter-cropped with small bush fruit and with vegetables. The varieties were high class dessert fruits mingled with a few cooking varieties.

The spraying was carried out on February 4th, 1927. The day was exceptionally mild and sunny with a good drying wind. A little rain fell during the night following. The spray was applied in part with a "Demon" power-sprayer and in part with knapsack sprayers.

OBSERVED, MAY 31ST, 1927.

Controls heavily infested with Leaf Curling Aphis, Leaf eating caterpillars and Tortrix larvæ.

Tar Distillate.	Aphis	80%	control.
	Caterpillar	80%	,,
	Tortrix	50%	,,
Wash A	Aphis	90%	,,
	Caterpillar	60%	,,
	Tortrix	60%	,,
Wash B	Aphis	90%	,,
	Caterpillar	60%	,,
	Tortrix	70%	,,

The above percentages are gathered from fairly careful observation and are only approximately accurate. At the same time they are very fairly correct if taken as a comparative estimate of the quantity of pests present on the trees.

OBSERVED, AUGUST 17TH, 1927.

No difference between the three sprayed blocks could be seen. All sprayed trees were very clean and carried a good crop. Capsid not plentiful enough to remark upon.

The unsprayed controls were easily discernible to the eye. The fruit on them was in all cases shrivelled and dropping, while the new wood was distorted and crippled by aphis attack.

Remarks.

On the whole washes A and B appear to be as efficient as a good tar distillate wash, except perhaps against caterpillars of the Winter Moth Group. The staining of hands and clothing by these washes is undoubtedly a disadvantage, unless they are used by trained men, properly attired. Although rain fell soon after the application of the washes, they had already dried, and no washing off was observed. Undercrops, notably autumn sown beans were completely destroyed by the washes, and this point must be borne in mind when using them. It is hoped to make further trials with di-nitro-cresol washes during the coming winter.

W. E. H. Hodson,
Advisory Entomologist.

September 6th, 1927.

REPORT ON SPRAYING TRIALS WITH DINITRO-CRESOL IN THE WEST MIDLAND PROVINCE, 1927.

In conjunction with a series of trials of tar-distillate winter washes,* two experimental washes (A and B), received from the Rothamsted Experimental Station, were compared with a proprietary tar-distillate wash which has consistently given good results. The composition of the diluted Rothamsted washes were as follows :—

Wash A contained 0.2 per cent. dinitro-cresol and 2 per cent. of an emulsified disinfectant used as solvent.

Wash B contained the sodium salt of dinitro-cresol equivalent to 0.2 per cent. dinitro-cresol with 0.5 per cent. of soap.

The tar-distillate wash was used at a strength of 10 per cent. on apples and 6 per cent. on plums.

Six trees were sprayed with each wash and ten trees were retained as controls. Where possible a chequer board scheme was employed in the lay out of the experiment. Details of the work are supplied in the Table below, where each orchard is given a key letter in order to facilitate the tabulation of the results.

* Full details of these trials are reported in J. Min. Agric., 1928, **34**, 1107.

Orchard.	Key letter.	Fruit.	Date of Spraying.	Date of Examination.
Co-op. Wholesale Society Estate, Roden, Salop.	A	Apples (Bismarck) Plums (Victorias) Damsons.	Feb. 8th. Jan. 31st. Dec, 19th, 1926.	May 18th. May 20th. May 20th.
Mr. Venables, Moreton, Staffs.	B	Damsons.	Dec. 20th, 1926.	May 5th.
Mr. Percival, Rodbaston, Staff.	C	Apples (mixed) Plums (mixed)	Feb. 9th. Jan. 20th.	May 5th. May 5th.
Mr. Blackwell Sims, Bickmarsh Hall, Bidford-on-Avon, Warwick.	D	Plums (Czar) Apples (Worcester)	Jan. 19th Jan. 19th.	May 9th. May 9th.

APPLES.

Orchard.	Pest.	Control.	Tar Distillate.	Wash A.	Wash B.
A	Winter Moth Caterpillar.	12	6	10	14
	Capsid	17·4	9·5	15·5	18
C	Winter Moth Caterpillar	15	8	11	15
	A. pomi	1	—	Tr.	Tr.
	A. roseus	1	—	—	Tr.
	Psylla	1	—	Tr.	Tr.
D	Winter Moth Caterpillar	7	2	2	3
	Capsid	24	2	7	10
	Psylla	3	—	2	3

SYSTEM OF MARKING.

Winter Moth Caterpillar.

The figure given is an estimate of the actual number of caterpillars per tree, and represents an average obtained from counting every individual tree.

Psylla and Aphis.

A figure of 10 is given where the attack is very heavy and this figure falls to 1 where the attack is slight. Tr. = trace, indication that a few scattered individuals were present.

Capsid.

The figure given represents the percentage number of leaf trusses showing characteristic markings. As with Caterpillars, the figure is the average arrived at after estimating each tree.

DAMSONS.

Orchard	Pest.	Control.	Tar Distillate.	Wash A.	Wash B.
A	Leaf Curling Aphis	13%	Nil.	Nil.	Nil.
	Winter Moth Caterpillar.	No estimation possible.			
B	Leaf Curling Aphis	25%	1%	1%	2%
	Winter Moth Caterpillar.	No estimation possible.			

PLUMS.

Orchard	Pest.	Control.	Tar Distillate.	Wash A.	Wash B.
A	Leaf Curling Aphis.	2%	All trees showed less than 1% leaves curled.		
	Winter Moth Caterpillar.	No estimation possible.			
D	Leaf Curling Aphis	30%	All less than 1% of the leaves showing curling.		
	Winter Moth Caterpillar	10%	No appreciable reduction in numbers.		
C	Leaf Curling Aphis	Nil.	Nil.	Nil.	Nil.
	Winter Moth Caterpillar	30	15	10	10

SYSTEM OF MARKING.

Leaf Curling Aphis.

The figure is again an average one, representing the percentage of curled leaves on the tree.

Winter Moth Caterpillar.

The figure given is an estimate of the actual number of caterpillars per tree, and represents an average obtained from counting every individual tree.

DISCUSSION OF RESULTS.

APPLES.

Aphis and Psylla.—Throughout the orchards under experiment, the infestation on the controls was very slight. Eggs were found in small numbers only at the time of spraying and it is probable that the severe frosts in the autumn of 1926 were responsible for this as many oviparous females were destroyed before the eggs were laid.

The tar-distillate wash gave a complete control but the two washes A and B were not so satisfactory, small numbers of insects being present regularly on the sprayed trees.

Winter Moth Caterpillar.—The results show that all the washes used had some effect in reducing the number of Caterpillars but they cannot be relied upon to give a tree clear of Caterpillars.

Capsid Bug.—The distribution of the insects was very uneven, and there is no satisfactory evidence of control by any of the washes.

PLUMS AND DAMSONS.

Leaf Curling Aphis.—All three washes seem to give a very satisfactory kill on the eggs of this aphis. For all practical purposes the trees sprayed were clean while the controls showed a fairly heavy percentage of leaves curled.

Winter Moth Caterpillar.—Owing to the size of the trees it was impossible to estimate the actual number of Winter Moth Caterpillars on them. There is every reason to believe that the position of this pest on plums, is similar to that on apples and though sprayed trees appeared to be definitely more free from Caterpillars than the controls, they were by no means free altogether.

Bud Scorch.—In no orchard this year was any case of Bud Scorch observed. All the sprayed trees carried as heavy a blossom as the controls and showed a very much superior wood growth.

S. J. JARY,
Advisory Entomologist.

September 22nd, 1927.

WINTER WASH TRIALS IN CAMBRIDGESHIRE, 1927.

These trials were carried out in conjunction with Mr. A. T. Paskett, the County Horticultural Advisor, at Waterbeach. The orchard consisted of twenty rows, alternately Czar plums and Bramley's in each row. Only the plum trees were sprayed. The trees were about fourteen years old and many of them had grown very badly; most of them had dead branches caused by Die-back (*Monilia*) and some of the trees had died and had been removed. Spraying was carried out on the 14th January, 1927, on a moderately windy day. An estimate of the damage due to aphis and caterpillars, and of the crop of fruit, was made on May 30th.

The following table gives the results obtained :—

	No. of Trees.	Percentage of leaves curled by aphis	Percentage damage due to caterpillars.
Control	20	21	3·7
Tar Distillate Wash 10 per cent.	14	nil.	about 1%
Dinitro-cresol	16	nil—trace	about 1 %
Sodium dinitro-cresol and soft soap ..	17	nil—trace	about 1 %

The dinitro-cresol emulsion and the sodium dinitro-cresol and soft soap gave a complete control of leaf curling plum aphis on some trees. The average percentage of leaves curled by aphis on the control trees was over 20%. The tar distillate wash gave a slightly better control than the other two washes, due probably to the fact that it is easier to cover the trees with this wash when there is a moderate amount of wind.

All three washes gave a marked reduction in the amount of caterpillars, but there was very little difference in any of the sprayed trees. There were very few red spiders (*Oligonychus ulmi*) on any of the trees. The tar distillate wash appeared to have reduced the amount of fruit slightly, whereas the dinitro-cresol and the sodium dinitro-cresol and soft soap appeared to have increased the crop. Owing to the variation and state of the trees it was difficult to estimate accurately the effect of the spraying on the yield of fruit. For killing the eggs of leaf curling plum aphis and caterpillars, the dinitro-cresol and the sodium dinitro-cresol and soft soap gave very similar results to that of the tar distillate wash used. There is, however, one great disadvantage to the use of these two washes, namely, that they stain the clothes and skin of the operator a picric yellow colour, and we are of the opinion that it will be extremely difficult, and in many cases impossible, to get workmen to spray trees with these washes day after day. Before these washes can be recommended, information of their effect on the health of the operators should be obtained.

F. R. Petherbridge.
W. A. R. Dillon Weston.

WINTER WASH TRIALS IN THE ISLE OF ELY, 1927.

These trials were carried out on apple trees in an orchard belonging to Mr. J. A. Clarke at Wisbech St. Mary. Alternate rows consisted of Bramley's with intervening rows of Newtons, Derbys, Lane's and Grosvenor's. Each sprayed plot consisted of six Bramleys, one Newton, two Derbys, two Lane's and one Grosvenor. The control plots were situated between the sprayed plots. The trees were about sixteen years old and in 1926 suffered from a bad attack of Rosy Aphis, although they had been lime sprayed the previous winter. The spraying was carried out on the 1st February, 1927, on a moderately windy day. The following washes were tested :—Dinitro-cresol, Sodium dinitro-cresol and sodium caseinate, and a Tar Distillate wash at 10 per cent. concentration.

The water used in the spraying was a very hard dyke water, and for this reason sodium caseinate made up as follows :—

3 ozs. Caustic Soda,
20 ozs. Commercial Casein,
2½ gallons of water

was substituted for soft soap in the sodium dinitro-cresol spray at the rate of 1 quart to 100 gallons.

An estimate of the damage done on the various plots was made on June 8th. Unfortunately the attack of Rosy Aphis was very slight indeed, and on some of the control trees no trace of Aphis could be found, but on a number of others there was a slight attack.

On the tar distillate plot no trace of Aphis was found on any of the trees; the other two plots were about intermediate in attack between the tar distillate wash and the control plots.

The caterpillar attack on many of the control trees was only slight, whereas on a few of the other trees, the attack reached what we call "slight to moderate." All the sprayed plots showed less damage than the control plots, but in our estimation, the tar distillate wash gave rather better control than the other two sprayed plots, which were about equal.

From these observations it will be seen that the tar distillate wash gave rather better control of both Aphis and caterpillars in this particular experiment. It is unfortunate, however, that the control plots were only slightly attacked.

The disadvantage of the staining properties of the Dinitro Cresol washes is referred to above.

F. R. PETHERBRIDGE.
W. G. KENT.

WINTER WASH TRIALS IN BERKSHIRE, 1926-27.

Experiments were made at two centres with the dinitro-cresol washes (A and B) supplied by Rothamsted Experimental Station.

Centre I.—Apples were sprayed on the 20th December, 1926. The trees consisted of a number of different varieties, mainly dessert fruits. Observations and counts were made during the latter part of May and early June. The figures obtained are summarised in the following Table :—

	No. of Trees.	No. of blossom trusses and shoots.	No. attacked by caterpillar.	% attacked by caterpillar.	No. attacked by Psylla.	% attacked by Psylla.
Control	5	414	48	11.4	171	41.3
Wash A	7	693	73	10.5	179	25.8
Wash B	8	669	84	11.1	155	23.2

Centre II.—Apples were sprayed on the 10th January, 1927, equal numbers of the varieties "Newton Wonder" and "James Grieve" being utilised. The counts were again made during the latter part of May and early June, and the figures are summarised below :—

	No. of Trees	No. of blossom trusses and shoots.	No. attacked by cater-pillar.	% attacked by cater-pillar.	No. attacked by Psylla.	% attacked by Psylla.
Control	12	360	102	28.3	209	58.1
Wash A	12	360	58	16.1	134	37.2
Wash B	12	420	72	17.1	110	26.2

Neither of the washes gave satisfactory control of caterpillar or Psylla.

Many plum trees, young and old, were sprayed, but it was not possible to obtain accurate records of the results. So far as visual estimation goes, neither of the dinitro-cresol washes appeared to have given as good a control of *Aphis pruni* as a good tar-distillate wash.

F. O. MOSLEY.

EXPERIMENTS AT LONG ASHTON.

Details of these trials have not been received, but Mr. A. H. Lees, writing on June 10th, 1927, reported that "We put the main part of the liquids on outside apple trees. The two chief pests present on the controls were Aphis eggs and Winter Moth eggs. On the date of examination the controls showed very little Aphis, but a fair amount of caterpillar and caterpillar damage. The sprayed rows, both A and B, numbering sixteen in all, were almost entirely free from caterpillar and caterpillar damage."

CONCLUSIONS.

It will be seen from the above reports that, except in one case, the washes containing dinitro-cresol or the sodium salt at a concentration of 0.2 per cent. showed approximately the same efficiency in controlling aphides and winter moth on apples and plums as a good tar-distillate wash at 10 per cent. There are minor variations in the estimated degree of control at the various centres, but in view of the fact that in no case was the infestation of the control trees very heavy, such variations are doubtfully significant. Attack by winter moth caterpillars was reduced but not eliminated, and this is in agreement with previous results.

The results of the experiments carried out in Berkshire differed, however, from those obtained elsewhere and indicated but little reduction of caterpillars and only partial control of Psylla.

There is no satisfactory evidence of any effect on Capsid eggs. No important differences between the results obtained with the two washes, A and B, were noted.

Both dinitro-cresol and the sodium salt are highly coloured substances and their solutions or emulsions stain the skin and clothes yellow. The colour is removable without great difficulty after several washings, but workers naturally dislike being coloured yellow and this property is a disadvantage from the practical point of view. No other difficulty was met with during the actual spraying operations except in one case, where, owing to extremely hard water, it was found necessary to use casein instead of soap with wash B.

In no case was any injury to the trees reported.

(*Received* 29/2/28.)

BOOK REVIEWS.

INTERNATIONAL CONFERENCE ON FLOWER AND FRUIT STERILITY.
New York, 1926.

THE papers presented at the International Conference on Flower and Fruit Sterility held in New York in 1926, under the auspices of the New York Horticultural Society, have been published as Volume 3 of the Society's Memoirs.*

The volume (which exceeds 400 pages) adds considerably to our knowledge of the problems raised by the occurrence of sterility in plants. Papers dealing with the many problems associated with incompatibility and sterility in Fruit Trees take up a considerable part of the volume and include the following contributions : " Pollen production and incompatibilities in Apples and Pears " by R. Florin, Sweden ; " Abortive and Sterile Apple Pollen," by E. Kvaale, Norway ; "Concerning the Sterility of Phanerogamic Plants," by D. Bois, France ; " Studies on the Sterility of Fruit Trees in Russia," by W. Pashkevitch ; " Self- and Cross-Sterility in the Japanese Pear," by A. Kikuchi, Japan ; " Sterility in certain Grapes," by T. Susa, Japan ; " Sterility in Fruits : a Summary of twenty years' study at the R.H.S. Gardens," by F. J. Chittenden, England ; " Studies in Relation to Sterility in Plums, Cherries, Apples and Raspberries," by M. B. Crane, England. The papers by American investigators which are of direct pomological interest include " Some factors to be considered in the practical application of sterility studies in Fruits," by A. J. Heinecke, " An evaluation of certain methods used in the study of the pollination requirements of certain fruits," by L. H. MacDaniels ; " Apple pollination studies in California," by E. L. Overholser ; " The results of cross-pollination between different varieties of Apples, Plums, Pears and Cherries," by R. Wellington ; " Field studies of the Pollination requirements of certain deciduous fruits under California conditions," by W. P. Tufts, A. H. Hendrickson and G. L. Philp ; " Sterility in Peaches," by C. H. Connors ; " Types of Sterilty in Plants and their significance in Horticulture," by A. B. Stout ; " Sterility in the Strawberry and its Solution," by G. M. Darrow ; " Relationship of Polyploidy to pollen sterility in *Rubus* and *Fragaria*," by A. E. Longley, and " Some Sterile and Fertile Plant Hybrids," by N. E. Hansen.

From a fruit-grower's point of view the conclusions to be drawn from these contributions are, that the practical and essential requirements of fruit trees for the setting and development of their fruits are : (1) an efficient standard of cultivation ; (2) the interplanting of self-sterile, and indeed any varieties which are not capable of producing a satisfactory crop with their own pollen, with other varieties with which they are mutually inter-fertile and which flower at the same time ; and (3) a sufficient number of flower-visiting insects to ensure cross-pollination.

With respect to our domestic plums and sweet cherries, it is abundantly clear, although a good deal of actual sterility is involved, that the main problem is one of incompatibility. A few cases are known where the complete or high degree of male sterility renders varieties useless as pollinisers, *e.g.*, the plum Golden Esperen. It is also clear in cherries and plums that self-sterility, or to write more correctly self-incompatibility, is a varietal character, which is as stable as any morphological character.

In pears and apples it is also evident that incompatibility plays a considerable part in the problems associated with fruit development, but it appears probable in these fruits that actual sterility plays a larger part than it does in cherries and plums. It may be pointed out that whereas a proportion of fruit to flowers as low as 5 per cent. may give a good crop in apples and pears, 30 per cent. or even higher may be necessary in cherries and plums. In addition the number of ovules per fruit is much higher in apples and pears. Consequently an economic yield can be maintained in spite of a higher degree of sterility in apples and

* *Memoirs of the Horticultural Society of New York*, Vol. 3. Edited by A. B. Stout. Pp. xi+408+30 plates. Published by The New York Horticultural Society, New York. 1927.

pears, than is possible in cherries and plums. Pending a critical cytological study, however, I doubt whether it will be possible to determine how much gametic and zygotic sterility prevails, or to explore fully the problems which concern fruit development and production in varieties of apples and pears.

The papers by Heinecke and MacDaniels stress what, in a broad sense, may be termed environmental factors. That the standard of cultivation is an inevitable consideration in all investigations and especially in relation to sterility in plants is beyond dispute, and consequently the measurements of compatibility or sterility obtained from 100 flowers, where the health of the tree is regarded as of the first importance and all other disturbances are eliminated, may be far more reliable and of greater value than results from 10,000 flowers when the health of the trees is in any doubt and external influences are not effectively controlled.

Although agreeing with MacDaniel's expression of dissatisfaction respecting such methods of technique as the removal of petals, stamens and the outer part of the calyx tube *en bloc* with the nails of the thumb and finger, his statement that " an ideal method for studying pollination problems in a practical way under reasonably well controlled conditions is yet to be found," reflects a scepticism which indicates that he is not fully acquainted with the facts.

The inadvisability of planting a newly-introduced variety, or indeed any variety, in isolation or in large blocks unless it is known to be capable of producing an economic yield with its own pollen, is amply demonstrated in the paper by Connors with respect to the peach variety, J. H. Hale.

The paper by Longley emphasises the relation of polyploidy to sterility and fruit production in our domestic fruits. In the forty-six horticultural varieties of *Rubus* studied by him none was found to possess an odd multiple of the basic chromosome number (seven). Triploid and pentaploid forms produce very little good pollen and are highly sterile, but the even multiples—the diploid, tetraploid, hexaploid and octoploid groups—have comparatively little sterile pollen. A brief consideration of some of the hybrid forms of *Rubus* with which we are familiar in this country, and which have been cytologically studied by my colleague, Mr. C. D. Darlington, will bring nearer home the importance of polyploidy and its relationship to sterility and fruit production. The Mahdi has twenty-one chromosomes, the Veitchberry twenty-eight, the Loganberry forty-two, and the Laxtonberry forty-nine, and as is well known the fertility and fruit production of the odd multiple forms, the triploid Mahdi and the heptaploid Laxtonberry, is much lower than that of the even multiple and balanced chromosome forms, the tetraploid Veitchberry and the hexaploid Loganberry.* Longley's work, and other cytological studies such as that of *Prunus* by Darlington, a summarised note of which appears in my own contribution, show that polyploidy has played an important and progressive part in the evolution of our domestic fruits.

To the geneticist the papers by Prof. E. M. East and A. J. Mangelsdorf of the Bussey Institution on " The genetics and physiology of self-sterility in *Nicotiana* " by Prof. E. Lehmann of Tübingen on " The heredity of self-sterility in *Veronica syriaca* and by Dr. M. J. Sirks of Wageningen on " The genotypical problems of self- and cross-incompatibility " are of exceptional interest. These investigators working with widely different plants arrived independently at conclusions which are essentially the same, and have provided a factorial interpretation of the phenomena of self- and cross-incompatibility which is of real significance.

The paper by F. G. Brieger and A. J. Mangelsdorf on " Linkage between morphological characters and factors for self-sterility " is noteworthy, as in addition to establishing a unique example of linkage, it corroborates East and Mangelsdorf's interpretation of sterility. To detail these investigators' interpretation of the heredity and genotypical behaviour of self- and cross-sterility would go beyond the scope of this note. It may, however, be mentioned that their results show that self- and cross-incompatibility is determined by genetic factors, just as are morphological characters, but the behaviour and inheritance of

* Owing to a peculiar aberration in the development of its anthers, which in our opinion is not connected with the general problem of fertility, the Veitchberry should not be planted alone.

incompatibility is naturally complex. In self-sterile individuals pollen can only grow and function on a stigma which is of a different genetic nature ; like repels like, and self- and cross-pollinations fail between individuals with the same genetic constitution with respect to sterility factors because the growth of the pollen tubes is arrested in the nutrient stylar tissue. Consequently groups of individuals occur within which all cross- and self-pollinations fail. Individuals also occur which differ when reciprocally cross-pollinated, i.e., the pollinations are effective when made one way, but fail in the other.

Since, as is shown in my own contribution many of our domestic cherries and plums fall into similar incompatible groups, the pomologist, no less than the geneticist, must be deeply concerned in the results of these experiments. Indeed, even at the present time it appears probable that the underlying principles are applicable to these fruits, although owing to their hexaploid and aneuploid chromosome constitution further complications may be expected.

It may be emphasised that incompatibility is only the result of likeness of sterility factors: morphologically the plants may be quite different, e.g., the cherries, Bigarreau de Schrecken, Bigarreau Frogmore, Belle Agathe and Waterloo are all in the same incompatible group, although they differ widely in fruit colour and in many other respects.

To the fruit grower the free production of fruit is of paramount importance. The setting and development of fruit takes a foremost place among the problems with which he is confronted, and as this is dependent on efficient pollination and fertilisation, the problems associaated with these processes cannot fail to be of vital concern to the pomologist and fruit grower. To explore these processes fully, or indeed to obtain any real knowledge of them, genetical and cytological studies are essential. Consequently although such studies are frequently regarded as within the realm of pure science, their practical importance is direct and self-evident ; to the breeder of economic fruits, the systematic pomologist and the fruit-grower alike they are invaluable.

Only the barest outline of those papers in the volume which are of direct interest to the pomologist is given in this report. Various aspects of sterility in many other economic and ornamental plants which take a prominent place in horticulture, are reported upon. The completion of this work brings us appreciably nearer to an understanding of the widespread phenomena of sterility, and the Horticultural Society of New York has reason to congratulate itself on the success of the conference. The whole volume reflects great credit on the Editor, Dr. A. B. Stout, and to the pomologist, the horticulturalist, and all interested in plants the volume cannot fail to be of real interest and value.

M. B. Crane.

UNIVERSITY OF CAMBRIDGE, DEPARTMENT OF AGRICULTURE FARM ECONOMICS BRANCH REPORT, No. 7.

THE ECONOMY OF A NORFOLK FRUIT FARM, 1923-26.

By C. W. B. Wright, M.A. (Lecturer in Horticulture) and R. McG. Carslaw, M.A. (Dip. Agric.Econ.)

This is a report of an investigation which was made during the years 1923-26 into the fruit costings of a farm in Norfolk. As the authors are careful to point out, the results of the investigation are of limited economic significance, since they are concerned only with one set of conditions over a relatively short period of time.

The variation of such important factors as climate, soil, distance of market, facilities for labour, and the management, preclude all possibility of generalising from the particular findings of this report, but within the limits of Anonyma Farm it is obvious that the results of the investigation are definitely significant in more than one direction, and it is to be hoped that the public minded owner of the farm will profit accordingly.

From a statistical point of view the report has a much wider interest since, for the first time, it publishes the results of costing fruit on a complete system of accounts.

With commendable courage the authors have ventured out into an entirely new field of statistical enterprise. As was to be expected they found many dragons in their path and if at times they may appear to have lost themselves in trying to elude the dragons, they have at any rate blazed the trail, and it is to be hoped, in the interests of all fruit-growers, that where these pioneers have led the way, others will not be afraid to follow.

THE JOURNAL OF THE SOUTH-EASTERN AGRICULTURAL COLLEGE, WYE, 1927, No. 24. Edited by the REV. S. G. BRADE-BIRKS. 7s. 6d.

Since 1913, it has not been found possible to issue the Wye College Journal as a regular annual publication, but with the present number it is hoped to return to the old arrangement, and its reappearance as a substantial volume is very welcome. The contents consist in the main of short reports on the activities of the various departments and of a number of original articles, chiefly on entomological subjects. It is not possible, in a brief notice, even to list the many interesting investigations which are summarised in the departmental reports, but the work of the Mycological Department on the Downy Mildew and Mosaic Disease of the Hop, and of Dr. Goodwin and Mr. Martin on lime-sulphur-arsenate mixtures and other spray fluids may be noted as of special interest to readers of this Journal. Lists of publications by members of the College Staff, covering the period 1923-27, are included in the reports.

Turning to the separate articles, Professor Theobald contributes a valuable account of the caterpillars and aphides which attack chrysanthemums under glass, drawing special attention to the increasing frequency of damage caused by larvæ of the Angle Shades Moth (*Phlogophora meticulosa*). With Mr. Barnes, he also describes a new species of gall midge (*Dasyneura arabis*, sp. nov.) infesting plants of *Arabis albida*. Two papers by Mr. Duffield deal with the Beet Eelworm (*Heterodera schachtii*) in hops, and with the damage done by the Blossom Beetle (*Meligethes æneus*) to swedes and turnips grown for seed. An account of British gall midges of economic importance, forming part of "Material for a Monograph of the British Cecidomyidæ" by Mr. H. F. Barnes, occupies some 80 pages. The midges attacking cereals, fodder crops, fruit, vegetables and miscellaneous crops are discussed in order, descriptions of each species are given together with notes on the life-history and possible control measures. It is of interest to note that one of the species included is the Chrysanthemum Midge (*Diarthronomyia hypogæa*), a serious pest in the United States, which has since been found attacking chrysanthemums in this country. A valuable bibliography is appended to the paper. The work of Mr. Barnes on British gall midges is adding greatly to our knowledge of an important, and rather neglected, group of insects.

The Journal contains many other articles of interest, but this short note will perhaps serve to indicate that, under the editorship of Mr. Brade-Birks, the reputation of the pre-war issues is fully maintained.

C.T.G.

BESCHRIJVING EN RANQSCHIKKING VAN IN NEDERLAND VOORTROMENDE KERSEN VORMEN. (DESCRIPTION AND GROUPING OF CHERRIES COMMONLY FOUND IN HOLLAND.) I.—RIETSEMA. H. Veenman & Zonen. Wageningen, 1928.

This is a thesis for a doctorate degree prepared by Mr. Rietsema, the Principal of the Catholic Agricultural and Horticultural School of Breda.

The author quotes and discusses the passages in which the classic authors mention the cherry, and describes the species from which they have been derived.

Many pages are then devoted to extracts from various pomological writers, showing the great variation in their descriptions, followed by a series of measurements of the different organs of the tree, and a discussion of their diagnostic value.

In the English abstract given, the author lays emphasis upon his method of description, which he says "might be called a quantitative method." He objects to such phrases as "rather large," etc., as they are only intelligible to those who are as well acquainted with the class of plants as the writer. He has made a large number of measurements to show, for

instance, how the internodes vary on the same shoot, the number of leaf serrations to the centimetre, etc.

Probably most sanguine pomologists have, in their early days, hoped to light upon some system by which fruits might be easily determined, some fool-proof system of classification. With increased experience, scepticism usually creeps in, and the conclusion is reached that there is but one way to know fruits well, that is to live with them and study them in different environments, and this long road has to be travelled by all who would arrive at deep knowledge, as in other things.

Dr. Rietsema quotes from many pomologists to show how their descriptions vary, but he does not specify one cause of difference, which is the scope and purpose of the author. There are popular works for the amateur and fully detailed ones for the expert, and no just comparison can be made between these two classes. Furthermore, certain authors of illustrated books have definitely limited their descriptions to characters not plainly shown in the figures.

That a greater uniformity of description is necessary is certain, but if we take some of the classics, such as Mas in France, we can hardly improve upon his list of characters or excel his faculty for the *mot juste*.

All writers have realised the variability of organs and have had to take a mean, selecting for instance the leaf on the middle of the shoot for description, or in fruits choosing the average specimen.

The key proposed by the author is on the usual botanical lines and is on a kind of "presence or absence" basis. This works out well with a small number of fruits such as the author describes, but its value, like those of all keys, can only be estimated when a larger number is dealt with.

We suppose most pomologists' paths are littered with rejected "keys," so attractive at first sight, but we hope the author will go on nevertheless and deal with some of the hundreds of Cherries that exist and so put his system to a full test.

The book represents an enormous amount of work and is presented in great detail.

As a contribution to our knowledge of cherry varieties the author would not himself claim a prominent place for his book, but it is a convenient summary of past work and opinion, and systematic pomologists will all welcome a recruit to their scanty company.

"ORCHARDING." By V. R. Gardner, F.C. Bradford and H. D. Hooker. Published by McGraw-Hill Publishing Co., Ltd., London. 1927.

There is not a dull page in these 300 vigorous pages by the authors of "Fruit Production." The book is written for beginners and aims at giving a comprehensive outline of the various phases of fruit production. Planned on such a generous scale, the book could not have been written without having recourse to generalisations and it is here that the authors lay themselves open to attack from the scientific pomologists.

One wonders for instance how much experimental data there exists for the very definite statement on page 4 as to the detrimental effect of deep cultivations at time of fruit setting and whether the statement refers to all hardy fruits.

With regard to rainfall again, if 30 inches of rainfall seem barely enough for successful apple growing in the States, it might be mentioned as a point of interest that the annual rainfall in Kent where the bulk of English apples are grown, seldom attains to 30 inches.

The most interesting part of the book, however, from the pomologist's point of view, is that which deals with manurial problems. For all practical purposes we are informed "the fertilizer problem in fruit growing is a Nitrogen problem." Again one is tempted to ask whether this refers to all fruits, since in this Country plums and apples do not appear to react in quite the same way to nitrogenous manuring.

Of Potash there is little or no mention and presumably the authors are satisfied that this is not an important factor in the nutrition of the fruit tree under their conditions. In view of Mr. T. Wallace's work at Long Ashton on this aspect of manuring this is as interesting as it is surprising.

THE RED SPIDER MITE.

(*Tetranychus telarius L.*)

By EDWARD SPEYER, M.A.

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THE Red Spider Mite is one of the so-called "spinning mites" and belongs to that family of the Acarina known as the Trombidiidæ. Though very abundant upon weeds, shrubs and even occasionally upon some trees in the open, the mite finds conditions under which plants are grown in glasshouses extremely favourable to its rapid reproduction during Spring and Summer, while the structure of the greenhouse affords it convenient situations in which to pass the Winter. In this way severe losses are occasioned to growers of cucumbers, tomatoes and carnations through the effect of vast numbers of mites partially destroying the foliage from which they obtain their nourishment. Red Spider mite is also a pest of the grape-vine, hops, legumes, strawberries, violets and sometimes of roses, arums, asparagus-fern, Salvia, peaches, nectarines and other fruit trees. It must not, however, be confused with the European Red Mite (*Oligonychus ulmi* Koch) so common on apple and plum trees.

Weeds, especially dead-nettle and convolvulus are favourable haunts, and their presence in the vicinity of glasshouses is often a source from which a valuable crop may become infested. The mite feeds and breeds practically without exception upon the under-surface of the foliage of plants, being found only very rarely upon the fruit of the cucumber plant.

The presence of the mite, the full-grown female of which measures only about one-fiftieth part of an inch in length, is indicated at first by a fine mottling of the leaf-surface through minute punctures or serrations made by the mandibular stylets which project forward from the pointed rostrum of the animal. Though the young may occasion slight markings, the principal disfiguration is produced by the adult female which feeds continuously by sucking the sap over wide areas of leaf-surface during its long egg-laying period (Fig. 3).

The leaf-cells in the neighbourhood of each puncture break down and dry out, so that in cases of severe attack, the foliage becomes hard and parchment-like and practically ceases to function. In general the lower leaves of a plant are first invaded, the young growth being avoided, but injury may result to the latter when the adults move upwards to spin extensive webs which are thick enough to prevent transpiration.

The general effect upon tomato and cucumber plants is to cause a hardness of growth which precludes breaking of new shoots, and cases have been recorded where tomato plants have actually died over comparatively large areas in which

the attack has been exceptionally severe. Much of the bloom upon carnation foliage is removed by the mite, the flower sepals being sometimes disfigured to an extent, which renders the flowers unmarketable.

It is only within the past seven years that the tomato plant grown under glass has suffered grave injury. Though some varieties of this plant are obviously more resistent to attack than others, no certain cause can be assigned to the recent adaptation of the mite to breeding extensively upon it. Manurial experiments have thrown no light upon the matter, and on certain extensive nurseries where cucumber plants have been infected for years, there is still no injury in the tomato houses. Though the hot moist atmospheres of the cucumber house are suitable to the breeding of the mite, increase of the latter is no less either in the drier tomato houses, or in carnation houses, which are both dry and cool. Infestations usually start on plants near hot pipes and near doors, where dry conditions prevail.

Seasonal Habits.

At the beginning of October, or later if heat is kept on, the adult female mites in cucumber and tomato houses assume a bright brick-red colour after fertilisation by the male, and leave the plants. It is from this hibernating form that the mite has obtained its common name. The red females wander into crevices in wood and brickwork, into hollow pieces of straw lying on the ground, into door-locks, and especially behind the iron hooks which support the hot water pipes. They also find their way up to the ventilators and ridging of the houses, while many actually creep outside and find shelter beneath the ventilator fittings.

Contrary to previous supposition, they do not remain inactive in winter, and upon any sunny day, even when the temperature is near freezing point, they will come out of their hiding places and run about actively in the sunlight. At this time they are gregarious, and collect together in masses often comprising vast numbers of individuals which spin webbing in which all move about to a considerable extent. At temperatures below freezing point they become inactive except in the presence of sunlight, but they will withstand for long periods degrees of frost far below those which they could possibly encounter in their natural environment. In absence of moisture, however, they die quickly under conditions otherwise favourable to them. For this reason weeds and pieces of moist wood (especially plant staging carelessly stacked amongst weeds or against hedges in winter) in the neighbourhood of glasshouses are chosen as places of hibernation, but upon the former the mites do not feed and rarely lay eggs in winter. Numbers of individuals have been kept from October to February in glass tubes where no nourishment could possibly be obtained, but in which a sufficient moisture was maintained to support life. Experiments,

supported by observations in glasshouses, have proved that in absence of sunlight the mites prefer a temperature near 50° F. and that they will move into higher or lower temperatures only when attracted to them by sunlight.

Accordingly, when the houses are heated and planted in January, there is a tendency for the mites to move to the upper portion of the houses where they obtain a suitable temperature. A little later some of the hibernating mites appear to drop to the ground, and wander on to the plants where they feed, gradually lose their red colour, and begin to lay eggs.

The female progeny of this first generation mostly turn red upon completion of their development and leave the plants for a period of about six weeks, during which time they behave as ordinary hibernating forms. The few which do not turn red continue to reproduce upon the plants. The middle of April usually marks the period when the majority of females come out of hibernation and invade the plants. From then onwards through spring and summer a continuous series of generations succeed one another and no red forms of females appear until autumn.

At almost any time from May onwards, and rarely even in March, the mites will become so numerous upon a single plant that their food supply begins to give out. Excessive activity is then shown, all stages assuming a pinkish colour especially the adults which, on tomato plants, congregate upon the topmost foliage and busily spin thick webs prior to quitting the plant for others where a good food supply is available.

On cucumber plants a single adult female drops from some point of vantage such as the tip of a leaf upon a strand of webbing often some two or three feet in length, down which many other individuals climb, and a mass of struggling mites remain suspended on the " rope " for many hours. Numbers fall off and seek other plants, and the rest, which are mostly adult females of pink but not a red colour, spin a compact silken cocoon about ¼ inch in diameter which hangs in mid-air. Within the cocoon the mites become temporarily quiescent but one by one they gradually escape over a period of some three weeks, and there can be little doubt that this curious habit is an adaptation to enable the plant to put out new foliage upon which the mites can feed and lay eggs at a later date. The spinning of cocoons is in no way connected with hibernation, though the " roping " period occurs usually during August and September. Sometimes a few eggs are deposited within the cocoon, but the young hatching from them probably do not develop. The cucumber plant apparently is the only one upon which cocoons are spun.

At the beginning of August there is often a more or less definite migration of adult mites from cucumber and tomato houses although the food supply may be plentiful. On a sunny day thousands leave the plants and escape from ventilators on to the ridge capping. Here they congregate in vast masses, and if

there is any wind, individuals detach themselves upon a short thread and are blown away. They appear to be carried considerable distances in this manner and are subsequently found laying eggs upon leguminous plants such as beans and red clover in the open.

If warm temperatures (above 64° F.) are available breeding at a slow rate may continue during the winter upon carnation and tomato plants, but on others, such as Banana, Datura, and Salvia, the mites remain inactive upon the foliage as the red hibernating form irrespective of temperature.

Upon carnations all stages in the life-cycle, including the eggs are usually of a distinctly red colour throughout the year, and a peculiar form of female, which occurs also rather rarely upon tomato plants is prevalent ; this is larger than the normal form and is of a brownish-red colour.

The Life-cycle of the Summer Generations.

When breeding occurs in the early year, development from egg to adult is slow and may extend over several weeks, but when temperatures rise in April a continuous sequence of generations follow one another rapidly with the production of yellowish or greenish adults.

The life-cycle of one such generation is as follows (see Figs. 1, 2, and 4) :—

The eggs, when newly laid upon the underside of the leaf amongst fine strands of webbing spun by the female, are semi-transparent, globular and whitish. They are hardly visible to the unaided eye. Shortly before hatching they become opaque and pink in colour. From three to nine days after laying according to temperature, the shell of the egg splits and from it there creeps the *Larva*, a feeble whitish object which differs from the subsequent stages in being of a round shape and possessed of only three pairs of legs. After some twenty-four hours the larva, which does not move far over the leaf surface, takes up a characteristic attitude, the two fore pairs of legs pointing forwards, parallel with the palps. In this position it remains motionless for another day, when the larval skin, underneath which a new skin has been developed, breaks and discloses the second or *Protonymph* stage. This is more active than the larva and resembles the subsequent stages in having four pairs of legs. While feeding, growing and often running actively over the leaf surface, during a period of some twenty-four to thirty-six hours, some protonymphs become much elongated, these being males, while the females remain more or less round in shape. (The sexes are really distinguishable from each other immediately on hatching from the egg, by the structure of the palps and claws of the first leg.) After a second resting stage similar to that of the larva, and occupying about thirty-six hours adult males emerge from the moulted protonymph skins, while the females after a resting period of some twenty-four hours moult and enter an additional stage, the *Deutonymph*, similar save in size to the previous one. The adult male is not

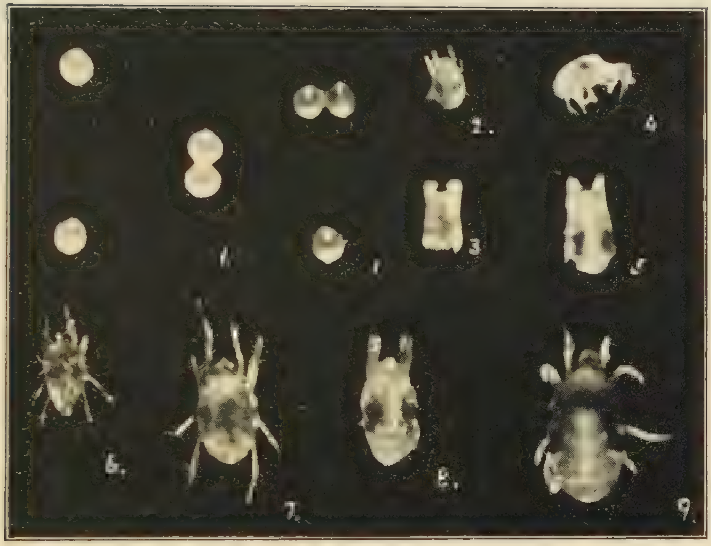

FIG. 1. RED SPIDER MITE (*Tetranychus telarius* L.). × 30.

1. Eggs.
2. Larva.
3. Larval resting stage.
4. Protonymph.
5. Protonymph resting stage (female).
6. Adult male.
7. Deutonymph (female).
8. Deutonymph resting stage (female).
9. Adult female.

FIG. 2. RED SPIDER MITE (*Tetranychus telarius* L.).
Eggs, Deutonymph, and Adult Male. × 60.

Fig. 3. Tomato Leaf showing injury from Red Spider Mite (*Tetranychus telarius*, L.).

Fig. 4. Red Spider Mite (*Tetranychus telarius* L.). Female × 130.

much more than half the size of the adult female and is easily distinguished from the latter by its attenuated shape. The males are active in seeking out female deutonymphs in the resting stage and then wait passively for the latter to effect the final moult. The deutonymph is active for a period of one day and a resting period of another day follows. Immediately after emergence of the adult female copulation takes place and the female starts egg-laying after some twenty-four hours. If no male is present, infertile eggs are laid within twelve hours of emergence, and these develop normally but to males only. Normally about 20 per cent. of the offspring of a fertile female are males, and the number of eggs laid by each female is in the region of 100. At first of a light straw or greenish colour, the female soon becomes distended with eggs which are deposited at the rate of about four a day over a period of three weeks. After feeding, black areas appear rather far forward to each side of the dorsal surface of both sexes, and a string of dark pellets make their appearance posteriorly in the duct of the excretory organ. In the female these dark globular products of digestion which are broken down in the alimentary sacs and reformed in the excretory organ become diffused over the whole abdomen, and give the mite a black appearance shortly prior to death. All active stages are able to spin a web which is formed as a secretion from a pair of large glands situated within and at the base of the palps. The actual thread, which is invisible even under very high magnification (300 diameters) is exuded from the tip of the ventral triangular maxillary plate, which projects anteriorly just beneath the tubular mouth.

THE CONTROL OF RED SPIDER MITE IN GLASSHOUSES.

Though of delicate structure and easily liable to mechanical injury, the red spider mite is notoriously difficult to kill by methods employed against insects or even other mites. It is possibly due to the circinate or fingerprint-like nature of the skin that sprays in ordinary use are comparatively ineffective as means of control. Fumigants such as hydrocyanic acid gas, nicotine, or tetrachlorethane, much favoured by the grower of glasshouse plants, for the control of White-fly and Aphids, appear to have no permanent action on the mite, even if used at concentrations far above those which growing plants will stand.

The nature of the breathing apparatus or respiratory system, which consists of fine tracheæ opening through a main trunk upon the underside of the rostrum, and of the skin, underlying which is an unbroken sheet of pavement epithelium, but most of all the absence of a circulatory system, are factors which must render the absorption into the tissues of gases and vapours in sufficient quantities to cause death, a matter of no small difficulty.

FUMIGANTS.

1. *Naphthalene.*

Pure commercial white-flake naphthalene was first used as a fumigant at the Cheshunt Experimental Station in October, 1923, and its vapour was found to be highly irritant to the mite, adults of which let themselves down from the foliage upon strands of webbing and remained struggling for many minutes or even hours until movement ceased. Early in 1924 experiments were carried out upon growing cucumber plants, and a high mortality of the mite was obtained in small glasshouses by broadcasting ordinary flake naphthalene upon the ground. Within larger spaces, it was necessary to divide up the flakes by passing them through a sieve, and it was finally determined that the best results were obtained when a sieve of 16 meshes to the inch was employed for the subdivision. Powdered naphthalene gave a low mortality. To obtain a complete kill of all stages of the mite, including the eggs, without injury to the foliage of cucumber plants, a strong persistent concentration of vapour, a temperature between 74°F. and 100° F. and a high atmospheric humid ty had to be maintained for a period of thirty-six hours. The minimum quantity of naphthalene to be distributed evenly over the cucumber borders was determined at 3 lbs. to 100 feet run of border, i.e. 6 lbs. to a house 100 feet long. The distribution of three times the amount neither increased the efficiency nor caused injury to the plants, but much naphthalene remained unvolatilised after thirty-six hours, and this was undesirable. During the growing season of 1924, about 5 acres of cucumbers under glass were treated with good results, except in a few cases where root action of the plants was weak or when the foliage was kept insufficiently moist by neglect of damping overhead during the period of fumigation. In 1925 pure commercial white-flake naphthalene suitably sieved was put on the market as a manufactured product known as Grade 16 Naphthalene. During July of the same year, it was proved beyond doubt that, given suitable conditions, the eggs of the mite are destroyed by normal fumigation as prescribed, a total of 679 observed eggs laid from four days previously up to the time of fumigation failing to hatch, while in untreated controls only 15 per cent. failed to hatch over the same period. On commercial nurseries ideal conditions for fumigation are seldom encountered, so that at least some eggs hatch out shortly after treatment : a second fumigation may, therefore, be necessary about one week after the first.

The cost of naphthalene fumigation in cucumber houses is less than one farthing per 1,000 cubic feet space and is therefore cheaper than any other known control measure. The method is now being largely and successfully exploited in Germany. As the fruit of the cucumber absorbs the vapour of naphthalene it is necessary to air the fruit after cutting for some four hours before

packing. Though a good control of red spider mite has sometimes been obtained in vineries, tomato, and carnation houses, successful fumigation with naphthalene cannot be relied upon in any of them, mainly owing to the difficulty of maintaining for so long a period as thirty-six hours the essential conditions of heat and humidity which are inimical to these plants. The volatilisation of naphthalene by mechanical heating devices has sometimes caused damage to plants grown on a large scale and should not be undertaken without considerable care. Good results have been obtained at the end of the growing season provided that the houses are kept at a temperature of 70° F. or above during fumigation. Broadcasting is useful in low cucumber houses shortly before the latter are cleared in autumn, as many mites are killed before they go into hibernation. The value of fumigation just before planting in January or February is questionable, as so many mites are situated on the outside of the houses, where the fumes cannot possibly affect them.

2. *Sulphur.*

The volatilisation of sulphur, as opposed to burning it to sulphur dioxide, is practised in vineries chiefly for the control of mildew. The process of fumigation is laborious and costly in labour, but a certain control of red spider mite is also obtained. Owing to mechanical difficulties in volatilising the sulphur without oxidisation, and the hardening effect of its vapour upon cucumber foliage, this substance is not considered a suitable fumigant for the control of the mite upon other crops grown under glass. The burning of sulphur just before the houses are cleared is not recommended, as the sulphur dioxide produced not only fails to kill the mites, but tends, through drying of the scorched foliage, to drive from the plants many female mites which are ready to hibernate, and would otherwise be removed from the houses upon the plants.

SPRAYS.

1. *Petroleum Emulsions.*

Whereas the lighter and cheap forms of burning paraffin are comparatively innocuous to Red Spider mite when their emulsions, at strong concentrations, are sprayed upon foliage, to which they may be extremely injurious, the heavier and more refined petroleum oils of .86 to .95 specific gravity (including medicinal paraffin, which is too expensive for general use) have a very marked action upon the mite, even when their emulsions, diluted so as to contain .75 to 1 per cent. of oil, are employed. When free from unsaturated hydrocarbons, from products of oxidisation (produced by heating in air) and from sulphur, emulsions of these oils do not harm the foliage of tomato, cucumber, and melon plants, and in some cases (notably that of the cucumber) no permanent injury will result from painting portions of the foliage with the pure oils. To obtain effective control of the

mite on a commercial scale, it is essential that the petroleum be emulsified with the smallest possible quantities of substances such as soft-soap and a caseinate, and that no spreader (such as saponin) be added to the spraying water.

The suitable types of petroleum readily cling to the chitinous skin of the mite, and the deposition of oil upon the foliage, though not entirely useless, is a secondary consideration. Too large a proportion of emulsifiers or the presence of a spreader appear to defeat the object in view, by causing the oil to run off the mites and foliage at the same time. A great advantage of spraying with such emulsions lies in the fact that hard water can be employed for dilution, as small a percentage as 7 per cent. of oil in a stock emulsion being sufficient to prevent the deposition of salts from hard water if a potash soft-soap is used as an emulsifier. On the other hand, these oils are difficult to emulsify except on a very small scale, even if organic liquids such as Fusel Oil are added to facilitate the process. The grower of glasshouse plants must therefore look to the manufacturing chemist to supply him with ready-made stock emulsion containing not less than 80 per cent. of a suitable petroleum oil. If a caseinate is employed as an emulsifier, some preservative must be added to prevent bacterial decomposition.

On no account should petroleum emulsions be used for the control of the Red Spider mite on carnation plants. The " bloom " upon the foliage absorbs the petroleum oil and is destroyed by it, and the mites do not receive enough oil to cause death. The best effect of spraying is obtained at high temperatures, and no injury to cucumber, melon, and tomato foliage has been observed from application in direct sunlight. If low temperatures prevail, a number of eggs may hatch, and the larvæ develop to maturity, so that a second spraying is necessary from seven to fourteen days after the first. Plants treated with the emulsion will require less water after application, owing to conservation of moisture at the leaf-surface. Both dropsy of the foliage and stems, and *Botrytis-rot* of the stems and trusses of tomato plants are greatly aggravated by too frequent spraying and indiscriminate use of petroleum emulsions, especially if the water requirements of the plants and houses are not carefully regulated after spraying. Plants which have been sprayed are not liable to reinvasion of the Red Spider mite for at least eleven days after application.

2. *Soft Soap and Liver of Sulphur.*

Neither soft soap nor liver of sulphur when used separately exert a good control over Red Spider mite, but a solution containing .5 per cent. of the former and .25 per cent. of the latter is probably more rapid in action than any other known spray: it is not so cheap but is more easily applied to thick foliage. The soft soap should be of a good " horticultural potash " brand, as excess alkali may be injurious especially to cucumber foliage. The great

disadvantages of the mixture are difficulties in preparation as far as concentrated stock solutions are concerned, and the absolute necessity of employing soft water, such as rain water, for diluting the stock and for spraying. The former difficulty can largely be overcome by the use of Fusel Oil, which is preferable to methylated spirit, for dissolving the soap, and the presence of this organic liquid (amyl alcohol) appears definitely to prevent the deposition of sulphur, so that concentrated stocks will keep for many weeks, if not permanently.

The stock is made up as follows :—

1. Dissolve 4 ounces ($\frac{1}{4}$ lb.) commercial Liver of Sulphur in 18 fluid ounces (to make 1 pint) cold distilled or rain water.
2. Heat in a large saucepan 8 ounces ($\frac{1}{2}$ lb.) horticultural Potash Soft Soap, with 4 fluid ounces Fusel Oil and stir until all the soap has completely dissolved.

When No. 2 is cold, strain No. 1 through a fine cloth into it, so as to remove small quantities of Iron sulphide, which is an impurity.

A dark orange, clear liquid is obtained, which, on standing for some time, separates into three clear layers : the mixture must, therefore, be shaken or stirred before use. For spraying use only rain-water or other soft-water, and dilute the stock at the rate of 1 part stock to 49 parts water : do not allow the diluted spray to stand long before use.

The whole stock is sufficient for 10 gallons of spray, costing less than 1d. per gallon. The use of this spray is indicated mostly for tomatoes ; it is the only spray which has been successful in controlling the mite upon carnations, the foliage of which is only stained to a slight degree by it. Slight scorching of tomato foliage may be expected if the spray is applied in hot bright weather, and brown marks upon the fruit necessitate wiping before sending to market.

3. *Flour Paste and Liver of Sulphur.*

The use of flour paste as a spreader and adhesive has met with disfavour amongst glasshouse growers, owing to the difficulty of making a homogenous solution without the formation of lumps.

> $1\frac{1}{2}$ ounces of wheat flour are made into a smooth paste with a little water : 2 pints of water are added, with stirring, so that no lumps of flour are formed. This is boiled with constant stirring and 1 ounce Liver of Sulphur dissolved in 14 pints cold water are added. The mixture will keep for a few hours only, and must therefore be used immediately.

For 100 gallons of spray, 5 lbs. flour and 3 lbs. Liver of Sulphur are required.

WINTER TREATMENT.

1. *Disinfection.*

(*a*) *Naphthalene.* The mechanical volatilisation of naphthalene by heat has already been alluded to, and there can be no doubt that very large numbers of red spider mite are killed if ten ounces crude naphthalene are evaporated to every 1000 cubic feet space over a period of 10-12 hours, provided that a temperature of 70° F. or over is maintained.

It is essential, however, to carry out fumigation not later than the middle of October, as the vapour will not destroy mites which have left the plants and reached places of concealment behind pipe-hooks, in hollow canes, or in pieces of straw lying upon the ground unless high temperatures can be maintained.

Suitable lamps for the purpose have been on the market for a considerable time.

If such fumigation has not been carried out, resort may be made to the use of cresylic acid as a spray, though this method is probably neither so efficient or economic as a means of killing the hibernating mite in large span houses in which tomato plants are usually grown.

(*b*) *Cresylic Acid.*—Shortly before cucumber and tomato plants are removed from the houses at the end of the growing season, the plants, glass, and woodwork are thoroughly sprayed either with a rough mixture of Pale Straw (98 per cent.) Cresylic Acid, 1 part to 40 parts water, or with 8 lbs. Potash Soft Soap dissolved by heat with 1 gallon Pale Straw Cresylic Acid, at the rate of 1 part of the mixture to 40 parts water. Care should be taken that the dilution of 1 in 40 is not exceeded in either case, and it is better to use the spray considerably stronger. The outside of the houses should also be sprayed, and a second application made three weeks before replanting in the early year. These sprays cannot be used upon or in the presence of growing plants, as the fumes of cresylic acid are exceedingly injurious to plant life. The ventilators of the houses should be kept closed for four days after spraying, and a good heat maintained in the houses.

2. *Trapping.*

At the beginning of October, where infestation has been severe in tomato houses, dry straw may be strewn over the ground surface between the rows of plants. Large numbers of female mites will enter the straw and may be destroyed by sweeping up and burning when the plants are removed. Strips of corrugated paper placed on the hot water pipes over the pipe-hooks also attract many thousands of mites at this time of year, and are removed and burnt at weekly intervals until the middle of November.

3. *Structural Cleanliness.*

The ridge-capping of houses should be raised from the apex of the roof and supported on bolts or nails so that a gap of at least $\frac{1}{4}$ inch is left between the two, or the ridge-capping may be entirely removed.

The use of canes as supports is to be avoided in all cases, as these harbour large numbers of hibernating mites which are exceedingly difficult to kill even by boiling water when lodged inside them.

Infection in the propagating house nearly always arises from staging which has been thrown amongst weeds or against a hedge and left thus during the winter. Not only is the spider mite introduced in this way, but several insect pests of importance to the grower of cucumbers also obtain access to the plants. Staging should, therefore, be well scrubbed after use and stored in a dry shed immediately after removal from the propagating house.

SUMMARY OF RECOMMENDATIONS FOR THE CONTROL OF RED SPIDER MITE IN GLASSHOUSES.

1. (*a*) Fumigation with crude Naphthalene, after the crop is finished, but not later than the middle of October, volatilised from lamps for at least 10 hours at a temperature of not less than 70° F.

(*b*) If Naphthalene has not been used a thorough cleansing of houses which have been infected during the previous season with Cresylic Acid and Soft Soap spray during winter.

2. The storage in a dry shed of staging when not in use for the propagating houses.

3. Early spraying of cucumber, tomato and melon plants, but not carnations, with a suitable petroleum oil emulsion, replaceable by soft-soap and liver of sulphur mixture which may be used for carnations when soft water is obtainable.

4. Spraying of cucumber and tomato plants with oil emulsion from the end of August till the crop is removed, to prevent mites leaving the plants for hibernation.

5. Fumigation by broadcasting Grade 16 Naphthalene for control of infestations during the summer in cucumber houses.

(*Received* 2/8/28.)

INVESTIGATIONS ON CHLOROSIS OF FRUIT TREES.

II.—THE COMPOSITION OF LEAVES, BARK AND WOOD OF CURRENT SEASON'S SHOOTS IN CASES OF LIME-INDUCED CHLOROSIS.

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Introduction.

In the previous paper of this series (1) results obtained on the composition of apple leaves in cases of lime-induced chlorosis were reported.

It was shown in that communication that chlorotic leaves showed lower contents of dry matter in fresh weight, higher ash in dry matter, and lower calcium and higher potassium in the ash than comparable green leaves and that, when appropriate treatments were given to the trees to restore the chlorotic leaves to a green condition, the characteristic features of the green leaves were also restored, i.e. dry weight increased, ash in dry matter decreased, the percentage of calcium in the ash became higher while the percentage of potassium was decreased.

Since the publication of the above results, the conclusions formulated have been tested in many cases over two further seasons and in every case they have been found to hold. In addition, examination has been made of samples of chlorotic foliage in cases of chlorosis of pears, plums and raspberries, all of which are susceptible to the trouble, and the investigation has been extended to the analysis of current season's shoots in certain cases.

The results obtained during the season 1927 on plum foliage and on current season's shoots of apples and pears and a single case of raspberries are reported in the present paper.

Experimental.

The centres selected were chosen as providing serious cases of the malady from which suitable material for analysis could be obtained.

Soil data showing the geological formations on which the centres occur and the carbonate contents of the soils are presented in Table I. Determinations of the pH values of the soils have also been carried out on most of the samples and these range from 7.2 to 7.6.

The values for carbonates show that these are high at all centres, though centres G. and I. show that it is not essential to have extremely high amounts present in the soil before lime-induced chlorosis can occur.

TABLE I.

Soil Data.

Centre.	Samples.	Geological Formation.	Surface Soil, Subsoil, etc.	Total Carbonates in air-dried soil. (Reckoned as $CaCO_3$). per cent.
A.	A, B.	Dolomitic Conglomerate ..	Surface ..	25.53
C.	C.	Keuper Marl	Surface .. Subsoil .. 18″—30″ ..	11.86 19.92 19.58
D.	D.	Chalk	Surface .. Subsoil ..	69.0 Not determined. (Chalk Rock).
E.	E, H.	Chalk	Surface ..	Not determined. High.
F.	F.	Thanet Beds—Chalk Mixture	Surface ..	Not determined. High.
G.	G.	Boulder Clay	Surface .. Subsoil ..	3.61 2.7
I.	I.	Lower Lias	Surface .. Subsoil ..	2.73 1.43
J.	J.	Drift over Lower Lias ..	Surface .. Subsoil .. 18″—30″ ..	7.02 12.66 16.94

MATERIALS ANALYSED.

In the cases reported in which data are given for leaves, bark and wood, the material usually consisted of the whole lengths of current season's shoots. In certain cases it was not possible to obtain such material owing to the fact that, in the chlorotic samples, the older leaves on the shoots were not entirely chlorotic. In such cases only the shoot portions bearing chlorotic leaves were taken and the corresponding "green" shoot samples were cut in such a way as to make them as comparable as possible. Terminal shoots were obtained wherever possible since these are more likely to be more comparable in age than laterals. There is, however, considerable difficulty in obtaining comparable samples since in serious cases of chlorosis shoot growth may cease entirely and, where shoot growth is appreciable on chlorotic trees, it frequently happens that the current season's shoots do not bear chlorotic leaves along their entire lengths. In the case of the raspberry, as will be seen from the notes, it was not possible to take anything like entire shoot lengths. In all cases the leaves used were those borne on the portions of the shoots actually utilised in the analyses.

The supplementary notes on the samples given below show the actual details of the trees, samples, etc., utilised in the work.

It was not possible in the present instance to carry out determinations of dry matter as many of the samples were obtained at some considerable distances from the Research Station.

NOTES ON SAMPLES.

Samples A.—These samples were taken from a single tree which was growing in a garden under conditions of high cultivation and manuring. The tree was probably about fourteen years old at the time of taking the samples. It had made good growth of shoots during the season. The samples taken were all of terminal shoots. The chlorotic leaves were yellowish white or white and often showed green markings along the veins. The green leaves were generally a fairly good green colour and showed a certain amount of the purple spotting which is a common feature of the variety.

Samples B.—These samples were also taken from a single tree, growing under similar cultural conditions and in near proximity to that from which samples A. were taken. This tree is also about fourteen years old. It had made some strong shoots during the season but it was difficult to obtain terminal shoots bearing wholly chlorotic or green leaves. The chlorotic leaves were generally yellowish white with green markings along the veins and the green leaves often showed a slight tendency to chlorosis.

Samples C.—These samples were collected from a group of trees growing in a commercial plantation. The trees were approximately twelve years old and many of them had suffered severely from chlorosis for several years whilst others had remained fairly free from the trouble. All samples were of current season's shoots but many of the shoots were lateral growths as the badly chlorotic trees had not made any appreciable growth of terminal shoots. In some cases of the chlorotic shoots, it was not possible to take the whole length of the season's shoot growth owing to the fact that the more basal leaves on the shoots were not entirely chlorotic.

The shoots comprising the "green" sample were in some cases taken from chlorosis-free trees and in others from trees only partly chlorotic. An attempt was made to obtain shoots as nearly comparable as possible as regards length, age, etc., with those of the chlorotic sample but perhaps the growths in the latter were less mature on the whole than those in the former.

Samples D. These samples were gathered from a batch of trees, about nine years old, growing in a commercial plantation in which practically all the trees were affected with chlorosis, the majority very severely. The green shoots were terminal growths taken from trees which were either free from chlorosis or

practically so and were generally vigorous. The chlorotic shoots were also terminals of fair vigour, the leaves being practically white.

Samples E. These samples were from a single standard tree, age unknown but over twenty years, growing in a garden under conditions of high cultivation and manuring. Although the tree was badly affected with chlorosis, certain branches were practically free from the trouble and the terminal shoots had made good growth. Terminal shoots of fair vigour were taken for both samples, the foliage on the green sample being a good green and on the chlorotic sample yellowish white.

Samples F.—These samples were from several trees growing in a commercial plantation. The trees had made excellent growth in the past but several had become markedly chlorotic during the last few seasons and in some cases shoot growth had stopped and the trees were in a critical condition. The trees were over twenty years of age and had been well managed and heavily manured.

Shoots of current season's growth, practically all terminals, were taken in both cases, the leaves of the chlorotic sample being white and of the green sample of normal colour.

Samples G.—These samples were collected from two year old trees worked on quince stocks and growing in a nursery. Many of the trees on the area concerned had either failed to grow or had made very poor growth due to chlorosis. Samples in both cases were of current season's terminal growths, the leaves of the chlorotic sample being white and those of the "green" a normal healthy green colour.

Samples H.—These samples were taken from plants growing in the same garden as the tree concerned in Samples E. The new season's canes were utilised for both samples, terminal lengths of about 1 foot being taken. The growths in the "green" sample were very strong and those of the chlorotic sample were also fairly vigorous. The chlorotic leaves were mostly entirely white.

Samples I.—These leaf samples were obtained from trees over twenty years of age growing in a commercial plantation. The trees had made excellent growth in the past and had been very profitable. Chlorosis had occurred sporadically over the whole plantation during the last few seasons and practically every tree was showing some chlorotic leaves. The leaves in both cases were taken near the bases of current season's terminal shoots. Most of the chlorotic leaves were yellowish white with green vein markings whilst the green leaves were a healthy green colour.

Samples J.—The trees from which these samples were collected were growing under commercial conditions. They were over thirty years of age and for several years had been affected more or less severely with chlorosis. When the samples were collected, it was very difficult to obtain a satisfactory

" green " sample as practically every leaf showed signs of the trouble. Mature spur leaves were taken as it was not possible to obtain comparable samples from current season's shoots.

Chemical Data.

The chemical data obtained on the " green " and " chlorotic " samples are presented below in Table II.

In all cases with the exception of samples I. and J. the results are reported for leaves, bark and wood. The " leaves " samples refer to the laminæ only whilst the bark samples include the bark and petioles.

Discussion of Results.

In order that the salient features of the results may be seen more readily, the points which merit attention have been summarised in a simple form in Table III.

The results obtained on the " leaves " for ash content in dry matter and percentages of calcium and potassium in the ash, with the exception of ash in Sample J., are in complete accordance with the results reported in the previous paper (*loc. cit.*).

In the case of the anomalous result for ash content in J., reference to the notes will show that in this case it was very difficult to obtain a satisfactory " green " sample whilst the difference between the two samples is only small. A similar result for " ash " on the same series of trees was also obtained in 1926. These results for leaves thus show that the findings previously recorded for apple leaves also hold for pear, plum and raspberry leaves.

The more important points relating to the contents of ash in dry matter and the important ash constituents in the ash of the leaves, bark and wood are as follows :—

Ash.—The ash in the dry matter of the chlorotic sample is high in leaves, bark and wood. There are only three exceptions to this and in each case the difference is small.

Iron.—In the chlorotic samples the iron content is more often low than high in the leaves but in the bark and wood it is practically always high.

Manganese.—The data for manganese are not very complete but they appear to show that in the chlorotic samples the element is generally low in the leaves. The results on the bark and wood are indefinite.

Calcium.—The results for this element are extremely definite in the leaves where the results for the chlorotic samples are invariably low. In the bark the differences are much smaller than in the leaves and in three cases out of eight the differences are insignificant. No clear point emerges in the results for the wood.

TABLE II.

Chemical Data.

Condition of Leaves.		Samples A. Apple, var. Cox's Orange Pippin. 3rd July, 1927. Leaf %	Bark %	Wood %	B.—Apple, var. Beauty of Kent. 3rd July, 1927. Leaf %	Bark %	Wood %	C.—Apple, var. Hector Macdonald. 8th July, 1927. Leaf %	Bark %	Wood %
Green	Ash in Dry Matter	5.85	7.38	3.92	8.00	8.23	3.44	7.16	8.68	3.31
	Fe_2O_3 in Ash	0.31	0.25	0.14	0.22	0.11	0.063	0.33	0.15	0.14
	Al_2O_3 in Ash	0.40	0.18	0.34	0.34	0.054	—	0.11	0.39	0.16
	Mn_3O_4 in Ash	0.033	0.024	—	0.069	—	—	0.091	0.036	—
	CaO in Ash	18.46	28.76	22.09	21.58	32.57	23.67	20.20	29.36	20.97
	MgO in Ash	7.00	5.49	4.08	4.35	5.32	—	8.32	7.82	7.05
	K_2O in Ash	28.62	19.66	24.07	33.81	19.82	28.11	31.11	20.79	28.27
	Na_2O in Ash	5.19	4.26	4.15	4.58	4.66	4.70	—	—	—
	P_2O_5 in Ash	10.02	4.72	7.56	5.17	3.74	6.45	9.40	5.46	13.01
Chlorotic	Ash in Dry Matter	9.27	8.96	5.74	11.22	8.79	3.72	8.27	9.47	5.18
	Fe_2O_3 in Ash	0.22	0.23	0.14	0.15	0.20	0.12	0.34	0.26	0.15
	Al_2O_3 in Ash	0.22	0.19	0.39	0.16	0.12	—	0.27	0.32	—
	Mn_3O_4 in Ash	0.018	—	—	0.005	—	—	0.034	0.033	—
	CaO in Ash	10.36	24.31	21.79	14.07	30.62	23.75	12.31	26.11	21.21
	MgO in Ash	3.42	5.64	3.53	3.81	5.02	—	7.08	8.00	7.77
	K_2O in Ash	45.14	29.71	24.54	41.67	22.03	26.47	39.32	23.71	24.05
	Na_2O in Ash	3.62	3.97	6.25	5.34	3.81	5.23	—	—	—
	P_2O_5 in Ash	8.73	5.22	7.40	5.06	3.70	6.65	10.28	6.17	11.15

TABLE II.—*continued.*

Condition of Leaves.		D.—Apple, var. Grenadier 5th August, 1927.			E.—Apple, var. Newton Wonder. 8th August, 1927.			F.—Pear, var. Conference, 5th August, 1927.		
		Leaf %	Bark %	Wood %	Leaf %	Bark %	Wood %	Leaf %	Bark %	Wood %
Green ..	Ash in Dry Matter	7.55	9.05	2.77	7.48	7.61	2.09	9.87	8.11	2.04
	Fe_2O_3 in Ash	0.41	0.21	0.14	0.45	0.13	0.27	0.10	0.13	0.20
	Al_2O_3 in Ash	0.39	0.64	—	0.17	0.15	0.066	0.09	0.034	Trace
	Mn_3O_4 in Ash	0.073	0.023	0.017	0.033	0.011	—	0.014	0.006	0.011
	CaO in Ash	22.71	36.35	25.38	21.17	29.33	10.06	38.23	39.37	24.67
	MgO in Ash	4.91	3.61	4.18	4.48	4.07	4.69	6.13	4.57	5.44
	K_2O in Ash	29.71	16.21	29.71	32.99	22.52	24.0	11.51	11.28	23.18
	Na_2O in Ash	1.10	2.20	1.62	1.43	2.92	—	2.3	1.61	2.41
	P_2O_5 in Ash	3.09	1.25	2.91	6.41	4.74	11.67	3.57	2.65	15.82
Chlorotic ..	Ash in Dry Matter	11.86	9.45	3.38	9.74	7.22	2.55	11.60	8.69	2.23
	Fe_2O_3 in Ash	0.35	0.37	0.24	0.37	0.20	0.26	0.12	0.15	0.10
	Al_2O_3 in Ash	0.45	0.58	—	0.15	0.12	0.06	0.07	0.01	Trace
	Mn_3O_4 in Ash	0.037	0.021	0.017	0.036	0.049	—	0.006	0.006	0.011
	CaO in Ash	13.87	36.14	26.33	11.45	25.02	7.92	28.66	39.23	26.27
	MgO in Ash	5.11	4.04	4.04	4.19	4.56	5.43	5.03	4.20	5.74
	K_2O in Ash	38.63	17.82	29.18	43.79	29.33	37.88	23.06	12.71	22.70
	Na_2O in Ash	1.21	1.81	1.75	1.77	—	—	2.46	1.03	2.11
	P_2O_5 in Ash	2.00	1.08	1.95	8.06	5.29	9.24	4.54	2.51	15.97

TABLE II.—*continued.*

Condition of Leaves.		G.—Pear, var. Conference 9th August, 1927.			H.—Raspberry, var. Lloyd George. 8th August, 1927.			I.—Plum, var. Pershore. 11th Aug. 1927	J.—Plum, var. Purple Pershore. 11th Aug. 1927
		Leaf %	Bark %	Wood %x	Leaf %	Bark %	Wood %	Leaf. %	Leaf. %
Green ..	Ash in Dry Matter	8.34	—	2.14	6.57	10.04	6.62	13.91	13.67
	Fe_2O_3 in Ash	0.23	0.11	0.02	0.24	0.11	0.11	0.115	0.068
	Al_2O_3 in Ash	0.38	0.15	0.16	0.25	0.06	0.07	0.074	0.16
	Mn_3O_4 in Ash	0.026	0.013	0.006	0.080	0.024	0.088	—	—
	CaO in Ash	27.10	35.32	15.75	17.08	14.78	13.08	29.25	31.29
	MgO in Ash	4.30	4.08	5.64	4.06	4.70	5.42	4.73	4.64
	K_2O in Ash	20.90	18.44	37.33	34.94	40.03	39.52	24.72	20.92
	Na_2O in Ash	1.86	1.24	2.51	2.96	3.48	3.50	4.2	3.97
	P_2O_5 in Ash	5.66	5.17	10.93	9.71	5.29	9.60	3.12	2.64
Chlorotic ..	Ash in Dry Matter	8.94	—	2.64	11.01	13.74	6.40	17.48	13.48
	Fe_2O_3 in Ash	0.28	0.13	0.04	0.20	0.20	0.16	0.15	0.082
	Al_2O_3 in Ash	0.56	0.56	0.10	0.28	0.068	0.077	0.20	0.09
	Mn_3O_4 in Ash	0.031	0.007	0.007	0.036	0.016	0.043	—	—
	CaO in Ash	19.25	29.25	12.52	14.96	15.35	15.88	20.24	28.15
	MgO in Ash	5.44	4.01	4.47	3.11	4.40	5.63	3.76	4.70
	K_2O in Ash	31.70	23.70	39.63	37.17	38.68	36.52	33.60	25.40
	Na_2O in Ash	1.41	2.30	2.29	2.17	3.37	3.80	2.07	3.68
	P_2O_5 in Ash	9.57	5.38	12.95	9.39	4.97	11.40	5.22	3.38

TABLE III.

Showing the relation between percentages of Ash in Dry Matter and percentage of certain Ash Constituents in Ash of Leaves, Bark and Wood in "green" and "chlorotic" samples.

Leaves, Bark or Wood.	Sample No.	Ash in Dry Matter.	Ash Constituents in Ash.					
			Fe	Mn	Ca	Mg	K	P
Leaves	A.	High	Low ..	Low ..	Low ..	Low ..	High ..	Low
	B.	High	Low ..	Low ..	Low ..	Low ..	High ..	Low*
	C.	High	Practically equal	Low ..	Low ..	Low ..	High ..	High
	D.	High	Low ..	Low ..	Low ..	High ..	High ..	Low
	E.	High	Low ..	Practically equal	Low ..	Low* ..	High ..	High
	F.	High	High* ..	Low ..	Low ..	Low ..	High ..	High
	G.	High*	High ..	High ..	Low ..	High ..	High ..	High
	H.	High	Low* ..	Low ..	Low ..	Low ..	High ..	Low*
	I.	High	High ..	— ..	Low ..	Low ..	High ..	High
	J.	Low*	High ..	— ..	Low ..	High* ..	High	High
Bark	A	High	Low*	— ..	Low ..	High ..	High	High
	B.	High	High ..	— ..	Low ..	Low* ..	High ..	Practically equal
	C.	High	High	Low* ..	Low ..	High ..	High ..	High
	D.	High*	High ..	Practically equal	Practically equal	High ..	High	Low
	E.	Low*	High ..	High ..	Low ..	High ..	High ..	High
	F.	High	High ..	Equal ..	Low* ..	Low ..	High ..	Low*
	G.	—	High ..	Low ..	Low ..	Low ..	High ..	High*
	H.	High	High ..	Low ..	High* ..	Low* ..	Low ..	Low
Wood	A.	High	Equal ..	— ..	Low* ..	Low ..	High* ..	Low*
	B.	High*	High ..	— ..	Practically equal	— ..	Low ..	High*
	C.	High	High* ..	— ..	High* ..	High ..	Low ..	Low
	D.	High	High ..	Equal ..	High* ..	Low* ..	Low* ..	Low
	E.	High	Practically equal	— ..	Low ..	High ..	High ..	Low
	F.	High	Low ..	Equal ..	High ..	High ..	Low* ..	High*
	G.	High	High ..	High* ..	Low ..	Low ..	High ..	High
	H.	Low*	High ..	Low	High ..	High* ..	Low ..	High

NOTES.—The expressions high, equal, low, denote whether result for "chlorotic" sample is higher than, equal to, or lower than the corresponding "green" sample.

* Denotes difference very small.

Magnesium.—The results for magnesium are very indefinite especially so in the bark and wood and no definite point emerges. In the leaves they are in the same direction as those for calcium in seven out of ten cases.

Potassium.—In the chlorotic samples potassium is invariably high in the leaves and with one exception is high in the bark but in the wood there is no clear relationship apparent, the results for the "green" samples being actually high in five cases out of eight.

Phosphorus.—The results for phosphorus do not show any definite point in either leaves, bark or wood. It is of interest, however, to note that the value for phosphorus may be high where that for potassium is high since it has been found by the writer in several cases of potassium deficiency (2 and unpublished data) that in such cases high phosphorus is associated with low potassium irrespective of phosphatic manuring. Presumably different factors are operating in the two cases.

Of the foregoing results obtained in this investigation, it seems important to focus attention more especially on those for dry matter in leaves, bark and wood, and for calcium and potassium in leaves and bark—especially in the former—as these points appear to be characteristic in cases of lime-induced chlorosis of the fruit trees examined and, whilst they are doubtless of importance to the fundamental problems of lime-induced chlorosis, it will be shown in a later paper of the series that they are also of importance in distinguishing between lime-induced chlorosis and certain cases of chlorosis due to potassium deficiency.

It also seems important to draw attention to the fact that, although in certain of the cases considered in this paper the chlorotic conditions have been greatly reduced in severity in past seasons by sprays containing sulphate of iron, the content of iron in the ash of the leaves of the chlorotic samples does not give a clear indication of iron deficiency while in the bark and wood the iron content is higher in the chlorotic than in the green sample in almost every case. These results suggest that the iron in the tissues is not present in a form in which it can fulfil its normal functions.

Conclusions.

The following are the main conclusions which may be drawn from the data presented :—

1. In cases of lime-induced chlorosis of apples, pears, plums and raspberries (one case only), the chlorotic leaves show the following characteristics when compared with comparable green leaves : a higher percentage of ash in dry matter, and a lower percentage of calcium and a higher percentage of potassium in the ash.

2. The bark of current season's shoots of apples, pears and raspberries (one case only) bearing chlorotic leaves also show high percentages of ash in dry matter, and low percentages of calcium and high percentages of potassium in the ash when compared with similar shoots bearing green leaves. The differences for calcium and potassium, however, are not so great as in the leaves attached to the shoots.
3. In the wood of shoots referred to in 2, the ash in dry matter is again higher in the chlorotic samples than in the "green" but, in this portion of the shoot, the relationships which hold for calcium and potassium in the leaves and bark are not found, the results being indefinite in character.
4. The iron content of the leaves of chlorotic samples is not consistently lower than in those of comparable green samples and, in the bark and wood, it is usually higher in the chlorotic samples than in the "green."

Summary.

The results of an investigation on the chemical composition of the leaves, bark and wood of terminal shoots in cases of lime-induced chlorosis of apples, pears, plums and raspberries are reported.

Data are presented for "chlorotic" and "green" shoots for ash in dry matter and ash constituents in ash.

It is shown that the results previously reported for apple leaves affected with lime-induced chlorosis hold for similar cases of leaves of pear, plum and raspberry—i.e., in the chlorotic leaves, ash in dry matter is high, and calcium is low and potassium is high in the ash.

These three characteristics also hold in the bark of chlorotic shoots but, in the wood, the relationship for calcium and potassium in the ash is not maintained.

Iron is frequently low in the leaves of chlorotic trees but is usually high in the bark and wood of the shoots bearing such leaves.

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The chemical determinations on the "chlorotic" and "green" samples have been carried out in the writer's laboratory by Mr. A. N. Dunsby, B.Sc.

The author records his thanks for the assistance rendered by these colleagues.

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INVESTIGATIONS ON CHLOROSIS OF FRUIT TREES.

III.—A CHLOROSIS OF PLUMS DUE TO POTASSIUM DEFICIENCY.

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In the course of investigations on "Chlorosis of Fruit Trees" and on "Leaf Scorch of Fruit Trees." a chlorotic condition of plum trees which is not a lime-induced chlorosis has been observed at several centres. The most serious cases noted have been of the variety Purple Pershore, which is apparently extremely susceptible to the trouble, but minor cases have been seen of other varieties and in particular of Pershore Egg where the soil conditions conducive to the malady have been exceptionally favourable for its development.

Since this type of chlorosis is of economic importance and where it occurs on calcareous soil areas may be easily confused with lime-induced chlorosis, it is important to show the distinguishing characters of the two types in order that the appropriate control measures may be applied. With this object in view, the problem has been investigated during the past three or four seasons and, in the present paper, evidence derived from some typical cases is presented and discussed which illustrates the salient features of the trouble and how it may be distinguished from lime-induced chlorosis.

Condition of Affected Trees.

Trees suffering severely from the trouble are usually materially stunted, do not make appreciable terminal shoot growth and have poor root systems. They are often quite loose in the ground and may be shaken with little effort. The leaves, especially in older trees, are below normal in size and from an early date in the season the margins become curled towards the upper surfaces so that these surfaces take the form of shallow channels. The chlorotic condition of the leaf is first developed along the margins and spreads inwards from the marginal areas between the veins towards the midrib. Usually strips of green remain along the midrib and the veins. The leaves do not generally become such a pure white as in severe cases of lime-induced chlorosis. The margins of the leaves may eventually show "scorching."

Affected trees have a tendency to form a large proportion of fruit buds and to carry heavy crops of small fruits which usually fail to swell normally, while the ripening processes appear to be delayed.

OCCURRENCE.

The occurrence of this form of chlorosis has been studied mainly in the fruit areas of the West Midlands. These investigations have shown that the trouble occurs where the soil conditions are such as to produce leaf scorch in such fruit trees as the apple, gooseberry, etc. In the Pershore and Evesham districts, it is of frequent occurrence in small areas wherever the coarse textured Bunter Drift material occurs to any considerable extent or on heavy Lias clay areas where drainage is defective. On the sandstone formations such as the Old Red Sandstone and the Keuper Marl, it is found on areas of light soil or on areas where the soil is close-textured and shallow and overlies an impervious unweathered subsoil.

In order to illustrate the conditions under which the trouble is developed, the plantation details of some typical severe cases are given in Table I. and soil data relating to these centres are presented in Table II.

Of the cases cited in Tables I. and II., five—A, C, D, E, F—are from the Pershore and Evesham Lower Lias area, and in three of these cases—A, C, D—the soil is open-textured due to "drift" and "wash" deposits whilst in the other two cases—E, F—the soils are heavier and the drainage is defective.

Centres B and H are cases in which the subsoils are composed of close-textured impervious material and are typical of many such cases occurring on soils of a "fine sand, silty" nature such as those over the areas occupied by the heavy Old Red Sandstone soils and the soils of the Keuper Marl formation.

Area G illustrates the case of a light soil overlying a sandstone outcrop and centre I. occurs on an area much affected by hill "wash" where the soil feels loose and works like a very light soil.

It will be noted that, in all cases, management has been of a normal character for cultivated plantations and it should be pointed out that, as is so frequently the case in commercial fruit growing, potash manuring has not been practised as a routine at any centre.

The following are the salient points revealed by the soil data given in Table II. :—

Centre A.—Surface soil and subsoil are fairly light, containing a fairly high proportion of coarse sand. Between 18 inches to 30 inches depth, the subsoil is very open, containing a high proportion of oolitic stones. "Available" potash is low and "available" phosphoric acid only moderate. Between 18 inches to 30 inches depth, carbonate of lime is very high.

TABLE I.

Plantation Details.

Centre	Samples	Particulars of Trees, etc.	Soil Features.	Management, etc.
A.	A1 to A5	Variety Purple Pershore. Half standard trees; age probably between fifteen to twenty years. Growth is very uneven over the plot, varying from fairly well-grown trees with normally green foliage to stunted trees bearing small pale leaves. Roothold is poor. The trees have a tendency to bear heavily but the fruit, especially on the stunted trees, is small, liable to drop and of immature appearance. Gooseberries on this area showed severe leaf scorch.	Site—practically level. The solid formation of the area is the Lower Lias. On the worst parts of the area the soil to a depth of several feet consists of a mixture of sandy Bunter Drift and Oolitic " wash " with some Lias clay. Previous to the winter of 1924-25 the drainage was moderate.	The area is a portion of a commercial plantation. Previous to 1921, management was only moderate but since then cultivation and spraying have been carried out efficiently. Annual dressings of organic fertilisers such as hoof and horn and bone manures have been given. During the last two seasons pigs have been folded on a portion of the area.
B.	B1 to B4	Variety Purple Pershore. Standard trees; age between fifteen to twenty years. Area partly interplanted with black currants. The trees have mostly made poor growth, have borne chlorotic foliage each season and are usually very loose in the ground. They crop heavily but the fruit is small and of poor quality. The black currants, variety Baldwin, have made good growth.	Site—gentle slope to east. Soil is derived from the solid formation May Hill Sandstone. Surface soil is shallow and of a fine sand-silty nature. Subsoil also consists of similar material, but of an unweathered impervious character into which the tree roots fail to penetrate.	The cultivation and management in this plantation have been excellent since planting. Organic fertilisers and a little stable manure have been given to the black currants as routine dressings.

TABLE I.—*continued.*

Centre	Samples	Particulars of Trees, etc.	Soil Features.	Management, etc.
C.	C1, C2	Varieties, Purple Pershore and Pershore Egg. Bush trees, age about ten years, interplanted with red currants. The trees of the variety Pershore Egg are generally well grown and foliage for the most part normal green. Practically all trees of Purple Pershore, foliage is extremely chlorotic; in the worst cases the chlorotic leaves also showing much edge scorching. The growth of these trees is stunted and the roothold is poor, many being loose in the ground. The affected trees crop heavily but the fruit is small and of poor quality. The red currants are stunted and show severe leaf scorch.	The site is level but on one side of the plantation there is a raised terrace. The area is a portion of an old river terrace and the soil which is of a coarse sandy-pebbly nature to a depth of several feet, is derived from re-sorted Bunter Drift material. The soil on the area on which the most severe chlorosis occurs appears to be coarser in the subsoil layers than that where chlorosis is less severe.	The land has been utilised for several years for intensive market gardening and fruit growing. It has been highly cultivated and manured with organic fertilisers.
D.	D1, D2	Varieties Pershore Egg and Purple Pershore. Half-standard trees, age unknown. There are also a few apple trees and gooseberry bushes on the area. The growth of of all trees and bushes is extremely stunted. The plums are chlorotic and show edge scorching.	The area is level, forming a portion of a river terrace. The terrace material is several feet thick and is extremely gravelly with occasional clay bands. The matrix contains a large proportion of coarse sand. The soil is generally very light and stony, being typical of the deposit.	The land has been used in the past for fruit and market garden crops but the results have evidently been unsatisfactory. At present cultivation is at a low level and the area is being opened up for quarrying gravel.

TABLE I.—*continued.*

Centre	Samples	Particulars of Trees, etc.	Soil Features.	Management, etc.
E.	E1, E2	Varieties Purple Pershore and Victoria. Half-standard trees, age about thirty-four years. Both varieties show chlorosis but Purple Pershore is most severely affected. Trees of the latter variety are restricted in growth but not severely stunted. No data available *re* fruit.	Site level at bottom of a very gentle slope. Soil is fairly heavy, consisting largely of Lower Lias clay with a mixture of gravelly drift material. The area adjoins a pool and drainage is bad.	The area has been used for many years for fruit and market garden crops. Cultivation has been good and in the past dressings of shoddy, farmyard manure and other organic manures have been regularly applied.
F.	—	Variety, Purple Pershore. Half-standard trees, age unknown but probably over thirty years. Growth poor and trees show partial stunting. Foliage is chlorotic with edge scorch and trees are often loose in the ground. They usually fruit heavily but quality of fruit is poor. Apples and black currants on adjoining land all show severe leaf scorch.	Site is almost level with a gentle slope to the east at the east end. The surface soil is a mixture of gravel and sandy drift material overlying blue lias clay at 18″ depth. Soil and subsoil often show brown mottlings due to poor drainage and the subsoil appears to "lie wet."	The plantation has been used for fruit and market garden crops for many years. It is highly cultivated and has been liberally manured with soot, hoof, guano and shoddy for many years.
G	—	Variety Pershore Egg. Half-standards, ages two and three years. Foliage strongly chlorotic and showing edge scorch. These trees have been planted to replace apple trees which had been useless on the areas due to leaf scorch.	Site is a gentle slope to south-west. The soil is derived from the Old Red Sandstone formation. Surface soil and subsoil to 18″ comprise a sandy loam. Below 18″ the subsoil consists of loosely packed sandy material overlying soft sandstone rock.	The plantation is nineteen years old and has always been kept well cultivated. Heavy dressings of organic fertilisers containing nitrogen and phosphorus have been given.

TABLE I.– *continued.*

Centre.	Samples.	Particulars of Trees, etc.	Soil Features.	Management, etc.
H.	—	Varities Purple Pershore and Pershore Egg. Half-standard trees, age fifteen years. The growth of the trees of both varieties is poor, the foliage being generally chlorotic.	Site slopes fairly steeply to south-east. The soil is derived from the Old Red Sandstone. Surface soil is a close textured silty loam and the subsoil consists of close-textured, dry, unweathered, fine sandy material which is impervious to water.	Management has been excellent in every respect since planting. Heavy dressings of organic manures containing nitrogen and phosphorus have been regularly applied.
I.	—	Variety Purple Pershore. Half-standard trees, age twenty-one years, interplanted with apples, variety Grenadier. The growth of the plums is very poor, the foliage being chlorotic with edge scorching. The trees fruit heavily but the fruit is of poor quality. The apples have made poor growth and have "scorched" severely each season.	Site is a medium slope to the west. The soil consists of fine-sandy material to the depth of the soil auger and contains pieces of limestone. The material constituting the soil is a mixture of Old Red Sandstone material and hill "wash" composed of Silurian Limestone.	For many years the plantation was highly cultivated and manured regularly with heavy dressings of organic manures such as shoddy, meat meal, bone manures, etc. Of late cultivation has been "low" and very little manure given.

Centre B.—Both surface soil and subsoil are of the close-textured fine sand, silty loam type. "Total" potash is high and "total" phosphoric acid low in both samples. "Available" potash and "available" phosphoric acid are low in both surface soil and subsoil. Both samples are devoid of carbonate of lime and show substantial "lime requirements."

Centre C.—At this centre, soil samples to 27 inches were taken from two adjoining areas—a "more chlorotic" and a "less chlorotic" area. The data from these show that while the soils on both areas are open-textured, the subsoil samples from the "less chlorotic" piece are substantially heavier than those from the "more chlorotic" area.

"Available" potash is low in all samples whilst "available" phosphoric acid is extremely high, being typical of a market garden area. Both areas contain some carbonate of lime, the surface soil of the less chlorotic area containing a much higher percentage than that of the more chlorotic piece.

Centre D.—Both surface soil and subsoil are open textured, containing high proportions of stones and coarse sand. "Available" potash is very low and "available" phosphoric acid high in both samples. The samples are devoid of carbonate of lime and are slightly acid in reaction.

Centre E.—Although both surface soil and subsoil contain fair proportions of stones and sand, the soil is heavy owing to the high clay content. "Available" potash is medium in amount and "available" phosphoric acid fairly high in the surface soil and moderate in the subsoil. The surface soil is well supplied with carbonate of lime whilst the percentage of this material is high in the subsoil.

Centre F.—The surface soil on this area is fairly open-textured containing a fairly high percentage of coarse sand but the subsoil is heavy and at 18 inches there is a bed of blue lias clay.

"Available" potash is low in both samples whilst "available" phosphoric acid is fairly high in the surface soil and low in the subsoil. Both samples are devoid of carbonate of lime and are fairly strongly acid in reaction.

Centre G.—Surface soil and subsoil are sandy loams but below 18 inches the texture is extremely open, due to a layer of fine sandy material derived from the underlying bed of soft sandstone.

"Available" potash is low in both surface soil and subsoil and "available" phosphoric acid is fairly high in the surface soil and low in the subsoil. Both surface soil and subsoil contain small amounts of carbonate of lime.

TABLE II.

Soil Data.

Mechanical Analysis Data.	Centre A.†			Centre B.†		Centre C.* More Chlorotic Piece.			Centre C.* Less Chlorotic Piece.			Centre D.*	
	Surface. %	Subsoil. %	18″—30″ %	Surface. %	Subsoil. %	Surface. %	Subsoil. %	18″—30″ %	Surface. %	Subsoil. %	18″—30″ %	Surface. %	Subsoil. %
Stones in Sample ..	1.50 (Oolitic Lime-stone)	7.1 (Oolitic Lime-stone)	33.3 (Oolitic Lime-stone)	Nil.	5.4 (Pieces of Sand-stone)	6.86	7.33	3.51	6.51	6.04	2.05	14.18	12.48
Fine Gravel ..	—	1.98	4.58	1.55	3.61	—	—	—	—	—	—	—	—
Coarse Sand	29.50	28.26	28.02	2.67	3.97	41.42	50.41	41.49	41.24	39.03	30.30	57.20	55.84
Fine Sand . ..	22.54	26.16	22.92	30.68	30.36	26.71	21.53	27.94	18.62	21.59	26.93	17.32	15.28
Silt	7.95	8.05	6.15	23.77	21.88	7.96	9.29	8.98	9.53	10.29	12.12	1.60	3.96
Fine Silt	11.35	10.25	7.90	21.79	21.23	3.63	4.19	7.01	6.83	8.00	7.44	6.78	4.26
Clay	14.95	15.95	12.00	10.35	11.94	10.68	9.70	9.29	11.83	16.63	16.36	9.95	13.91
Loss on Solution ..	—	—	—	—	—	1.91	1.43	1.11	1.86	1.31	1.52	0.83	0.77
Moisture	4.77	3.02	1.37	2.76	2.46	1.91	1.09	1.07	2.42	1.71	2.16	2.49	2.66
Loss on Ignition ..	8.41	4.33	4.40	5.08	2.66	4.76	2.94	2.37	7.57	4.07	3.27	3.77	2.88
Chemical Data.													
Total Potash (K_2O) ..	—	—	—	0.799	0.785	—	—	—	—	—	—	—	—
Total Phosphoric Acid (P_2O_5)	—	—	—	0.075	0.055	—	—	—	—	—	—	—	—
" Available " Potash (K_2O)	0.0075	0.0048	—	0.0058	0.0033	0.0046	0.0046	—	0.0092	0.0058	—	0.0053	0.0053
" Available " Phosphoric Acid (P_2O_5) ..	0.0113	0.0079	—	0.0079	0.0039	0.1163	0.1199	—	0.1356	0.1455	—	0.0793	0.0474
Carbonate of Lime .	0.66	1.68	16.34	Nil.	Nil.	0.11	0.07	0.11	1.31	0.43	0.21	Nil.	Nil.
" Lime Requirement "	Nil.	Nil.	Nil.	0.300	0.300	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Acid.	Acid.

† The Mechanical Analysis fractions in these cases are in accordance with the A.E.A. 1906 method of grading. * The Mechanical A

Centre H.—The surface soil is a close-textured loam containing high proportions of fine sand and silt fractions. In the subsoil, the percentage of fine sand rises sharply above that in the surface soil and the material containing the high percentage of fine sand is of an unweathered character.

"Available" potash in the surface soil is fairly high but is low in the unweathered subsoil. "Available" phosphoric acid is fairly high in the surface soil and medium in amount in the subsoil. This soil contains only a small percentage of carbonate of lime but is not acid to 30 inches.

Centre I.—Both surface soil and subsoil are of a fine sand, silty nature and the mechanical analysis does not bring out the easy working loose nature of the soil.

"Available" potash is medium in amount in the surface soil and rather lower in the subsoil whilst "available" phosphoric acid is fairly good in the surface soil but only poor in the subsoil. There is a fair percentage of carbonate of lime in both samples.

In connexion with the above points shown in the soil data, it should be especially noted that in certain cases the soils are entirely devoid of carbonate of lime and may be definitely acid—e.g., centres B., D., F.—whilst, in others, the amount of carbonate of lime in the samples is as high as the amounts present in some cases of lime-induced chlorosis—e.g., centres A. (subsoil), E. The former category shows that the presence of carbonate of lime in the soil is not an essential for the development of the chlorotic condition whilst the latter shows the necessity of distinguishing between the two types of chlorosis.

FOLIAGE DATA.

Samples of green and chlorotic leaves have been taken from trees at five of the centres for chemical examination and the data obtained on these samples are shown in Table III. At the centres considered, it has been usual to find that the degree of chlorosis on the various trees differs appreciably, certain trees being very badly affected whilst a few usually remain either quite green or are only slightly affected. In obtaining samples of leaves for analysis, the method adopted has been to obtain samples from trees carrying green leaves for the "green" sample and from others bearing badly affected foliage for the "chlorotic" sample. In all cases the "chlorotic" samples have been composed of severely affected leaves, the only green showing on them being along the regions of the midribs and veins. As badly affected trees do not make appreciable shoot growth, the leaves in all cases are "spur" leaves. Only the laminæ of the leaves were utilised in the analyses. In two cases—A, B—the comparisons have been made in two different seasons.

It is important to note that samples A, C, D are from trees growing on light soil areas, samples B from trees on an area with an impervious subsoil and samples E from a heavy soil area with defective drainage.

The salient points in the data are as follows :—

1. Ash in dry matter is invariably lower, and usually considerably lower, in the chlorotic sample than in the green.
2. In all cases examined the percentage of iron is higher in the ash of the chlorotic leaves than in the green.
3. The percentages of calcium and magnesium in the ash of the chlorotic sample are always higher than in the green.
4. The percentage of potassium in the ash of the chlorotic sample is always extremely low, often being only of the order of 50 per cent. of the percentage in the corresponding green sample and in one instance being below 20 per cent. of the amount in the green leaves.
5. The percentage of phosphorus in the ash of the chlorotic leaves is with one exception higher than in those of the comparable green sample.

The Effect of Iron Treatment.*

In the seasons 1925 and 1926, spraying experiments with sulphate of iron were carried out on trees at centre A.

In the 1925 experiment, two trees were sprayed on May 15th with a 1 per cent. solution of ferrous sulphate and, in 1926, eight trees were sprayed on May 19th, using a 1 per cent. solution of ferrous sulphate containing 0.1 per cent. of an organic casein spreader.

In both seasons the sprayed and control trees were recorded for chlorosis in August and on both occasions it was concluded that no definite improvement in the quality of the foliage had resulted from the application of the sprays.

The Effect of Potash Manures.†

At centre G an opportunity has occurred of observing the effect of potash manures on the chlorotic condition on young trees. These trees were planted during the winter of 1923-24 to replace apple trees which had failed from " leaf scorch." From 1924 the area was utilised for an experiment to examine the effect of potash manures in controlling scorch. Six of the young trees were located on the " potash " plot and others were located on the untreated area.

* These spraying experiments were carried out in conjunction with Mr. R. C. Gaut M.Sc., Agricultural Organiser, Worcester C.C.

† The plantation at Centre C was dressed with sulphate of potash at 5 cwts. per acre—applied in two dressings—during the autumn of 1927 and the early spring of 1928. Following these applications, chlorosis was entirely absent throughout 1928 from the trees previously affected. (These results to hand since submission of paper for publication).

Potash manures were applied to the treated plot as under :—

1924—	Sulphate	of	potash	at	3	cwts.	per acre.
1925—	,,	,,	,,	,,	4	,,	,,
1926—	,,	,,	,,	,,	4	,,	,,
1927—	Muriate	,,	,,	,,	2	,,	,,

As the result of this treatment, the young trees on the potash plot have grown vigorously and carried green foliage since 1925 and have contrasted strongly with the comparable trees bearing chlorotic foliage on the untreated area.

In addition to controlling the chlorosis of the plums, the potash treatment has reduced the amount of leaf scorch on the apple trees on the treated plot to a marked extent and the experiment shows clearly that both apple and plum trees on the area have been suffering from deficiency of potassium.

DISCUSSION.

The evidence presented in the present paper shows that the cases of chlorosis considered are to be regarded as due to deficiency of potassium.

The field notes show that where such cases occur apple trees, gooseberry and red currant bushes, etc., when present, suffer from leaf scorch whilst the soil data clearly indicate that the soil conditions are typical of " leaf scorch " areas (1) and not of lime-induced chlorosis conditions although the soils may contain high percentages of carbonate of lime.

The foliage data also indicate potassium deficiency, the characteristics, low ash in dry matter, high calcium, magnesium and phosphorus together with low potassium in the ash, having been shown to occur in a proved case of potassium deficiency in gooseberry bushes (2, 3), and in other controlled cases of induced potassium starvation in pot and other experiments.*

Moreover, in the spraying experiments and the manurial experiments reported it is shown that ferrous sulphate used as a spray at an appropriate strength was ineffective in controlling the condition whilst potash manuring where tested remedied the condition.

The cases at centres B, E, F call for special comment. In a previous paper by the writer on " Leaf Scorch on Fruit Trees " (1) data were presented from several centres where leaf scorch had been substantially controlled by potash manuring. In all cases excepting one, the soils at the centres were of a coarse open-textured character, the exception being a heavy soil where drainage had been poor. It was thus shown that in such cases leaf scorch resulted from potash deficiency. There was no evidence presented to show that leaf scorch cases occurring on shallow close-textured soils with impervious subsoils were

* Unpublished data of the writer.

due to potassium deficiency although a case supporting the view was cited from the literature. The data presented in the present paper relative to centre B strongly support the view that in such cases trees suffer from deficiency of potassium, the percentage of potassium in the chlorotic foliage from this centre being especially low.

Centres E, F are typical cases of heavy soil areas with defective drainage and where lack of drainage is doubtless the primary cause of the chlorotic condition of the trees. The foliage data suggest that the trees are typically potassium deficient trees and lead to the interesting speculation that waterlogging induces deficiency of potassium. The writer has previously caused healthy gooseberry bushes receiving a complete nutrient solution containing an ample supply of potassium to " scorch " by waterlogging the root systems (1) and the experiment is being repeated in conjunction with the necessary analyses to determine whether the foliage and shoots of the waterlogged plants show the characters of potassium deficient material.

Thus the foliage data presented in the present paper suggest that in leaf scorch cases associated with the three classes of soils previously recognised, (1) scorching follows as the result of deficiency of potassium within the tree.

It is interesting to compare the results previously reported for the composition of chlorotic leaves in cases of lime-induced chlorosis (4, 5) with those obtained in the present instance for chlorotic leaves where the condition is due to potassium deficiency. In the former cases, the outstanding characteristics of the chlorotic leaves are high ash in dry matter and low calcium and high potassium in the ash, with usually low iron and magnesium in the ash whilst phosphorus is erratic though frequently high.

In the present cases, the conditions regarding ash in dry matter and calcium and potassium in the ash are the reverse of the above whilst magnesium and phosphorus are always high (one exception in the case of phosphorus).

It will thus be seen that the chemical examination of the foliage of green and chlorotic samples in cases where it is problematic as to whether the chlorosis is lime-induced or due to potassium deficiency affords a ready means of distinguishing between the two conditions.

Conclusions.

The following conclusions may be drawn.

1. A chlorosis of plum trees which has been observed in many commercial plantations is due to deficiency of potassium.
2. This condition in plum trees is developed under similar soil conditions to those conducive to leaf scorch in apple, gooseberry and other fruit trees.

3. Plum trees developing the particular chlorosis, whether growing on light open-textured soils, shallow close textured soils over impervious subsoils or on heavy soils with defective drainage, show similar conditions in the chlorotic leaves as regards ash in dry matter and the percentages of iron, calcium, magnesium, potassium and phosphorus in the ash when compared with the percentages of these in comparable green leaves. In particular, the chlorotic foliage shows low ash in dry matter, high iron, calcium, magnesium and phosphorus, and low potassium in the ash.

4. The composition of chlorotic leaves in cases of chlorosis due to potassium deficiency differs from that of chlorotic leaves in cases of lime-induced chlorosis in the following ways.
   In cases of chlorosis due to potassium deficiency, ash in dry matter is low, calcium in ash is high and potassium in ash is low, whereas, in lime-induced chlorosis, chlorotic leaves show high ash in dry matter, and low calcium and high potassium in ash.

5. Cases of lime-induced chlorosis and chlorosis due to potassium deficiency may be distinguished by the differences described in 4.

SUMMARY.

A chlorosis of plum trees due to deficiency of potassium is described. It is shown that the particular chlorosis is developed where the soil conditions are such as to produce leaf scorch of apple and certain other kinds of fruit trees.

Data relating to plantation details, soil characters and the composition of the foliage from " green " and " chlorotic " trees are presented.

The foliage data show that chlorotic leaves contain low ash in dry matter, high iron, calcium, magnesium and phosphorus together with low potassium in ash.

These characteristics of the chlorotic leaves afford a means of distinguishing the particular chlorosis from lime-induced chlorosis where ash in dry matter is high, and calcium low and potassium high in the ash in chlorotic samples.

The data from two centres suggest that water-logging may induce potassium starvation in plum trees.

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The analytical determinations on the foliage samples have been carried out by Mr. A. N. Dunsby, B.Sc.

The thanks of the writer are due to these colleagues for their assistance.

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TAR DISTILLATE TRIALS IN KENT AND WEST SUSSEX IN 1928.

By FRED. V. THEOBALD, M.A., V.M.H., F.E.S.

PART I.

SEVERAL spraying trials with Tar Distillate washes were carried out early in 1928 in Kent and West Sussex. The centres were at South Street, near Selling; at Otham, Beltring, Bearsted and Wye in Kent, and at Sompting near Worthing in West Sussex.

The trials at South Street and Sompting were mainly in connection with Capsid Bug control in Apples and at South Street on Capsid infested Black Currants. At Otham cob-nuts were sprayed and at Wye gooseberries for Gooseberry Aphis. The trees at the other places were sprayed for general apple insect pests, but, at Bearsted, especially for *Psylla*.

Altogether 385 apple trees and bushes, 576 black currants, 126 cob-nut and 24 gooseberry bushes were treated. The Tar Distillates used were Mortegg, Abolene, Carbokrimp, MacDougall's and, in one plantation, Voss's. The first three were kindly given by the makers.

Special thanks are due to Sir Walter Berry and Mr. J. Berry, to Mr. W. Chambers, Mr. Pullen-Bury, Mr. Bradley, and Messrs. Whitebread & Company for lending their plantations and orchards; to Mr. F. W. Costin, Horticultural Advisor of West Sussex and Mr. T. Parker.

Some of the general results at the various centres are recorded in Part I.; results dealing with Capsids in Part II.

1. On Gooseberries.

As no trials had previously been reported of the effect of Tar Distillate washes in controlling the Gooseberry Aphis (*Aphis grossulariæ* Kaltenbach), it was decided to spray some old bushes on the South-Eastern Agricultural College Farms, which were noticed to have numbers of oviparous females on them in the autumn of 1927, a year when *sexuales* of the Aphides were very abundant.

Twenty-four bushes in all were sprayed with Mortegg, Abolene and Carbokrimp on February 28th in fine weather.

Four control rows were left. A count of the Aphis colonies was made on June 20th and gave the following returns:

Row.	Spray.	No. of bushes.	Aphides.	Red Spider.
1	Control	8	160	70
2	Abolene	8	7	10
3	Control	8	98	14
4	Mortegg	8	10	2
5	Control	4	59	39
6	Carbokrimp	8	6	0
7	Control	8	151	101
8	Control	4	81	79

The Aphis-curled heads or tips were counted, and most of those that occurred on the sprayed bushes were low down. The Red Spider (*Bryobia ribis*) colonies were counted on April 24th. No other insects were present then. In June a very slight attack of Capsids took place, mainly on the lower parts. Sprayed bushes and controls were equally affected with Capsid.

Summary.—Tar Distillates are thus seen to have a very marked effect in reducing Aphis and also the amount of Red Spider. It was noticed, however, that the unhatched eggs of the Red Spider were not harmed, just as is found with the Apple Red Spider, the hatched Mites only were killed. The cleansing power of all the washes was good and about equal.

2. At Beltring, on Apples.

An old orchard of standard apples belonging to Messrs. Whitebread & Company at Beltring was chosen for experiment on account of its not having been sprayed for some time. An examination showed that it was heavily infested with Aphis and Psylla, a fair amount of Winter Moth and Red Spider eggs. There was also a lot of Case Bearer (*Coleophora nigricella*), and hibernating Gold Tail Moth larvæ ; some egg masses of the Vapourer Moth and a sprinkling of the Woolly Aphid and Mussel Scale were also present. The trees in fact were in a foul state. These trees were sprayed with Mortegg and Abolene only, two stregths of each being used. Seventy-six trees were sprayed and twelve left as controls. Spraying took place between February 17th and 20th. The weather at spraying time and afterwards was excellent. Mortegg was used at 7½ per cent. and 5 per cent., as were also both types of Abolene. Each tree took from seven to nine gallons of wash. A power sprayer was used with a No. 17 nozzle, the pressure being 100 lbs. to the square inch. A final examination of this plot was made on May 25th, the following being a summary of the counts :

Wash.	Row.	Ps.	W.M.	A.r.	R.P.	W.A.	Cap.	Tort.	Cole.	Total.
Control* ..	1	832	57	58	454	91	19	13	16	1518
Abolene A7½ ..	2	3	20	1	13	6	4	6	15	80
Mortegg 7½ ..	3	0	8	10	1	11	17	1	24	73
Abolene B 7½ ..	4	4	16	0	2	24	19	4	15	88
Mortegg 5 ..	5	0	22	3	7	19	29	8	10	98
Abolene A. 5 ..	6	0	19	5	13	14	19	7	15	92
Abolene B. 5 ..	7	0	33	12	7	10	19	4	11	96

* Four trees counted in Row 1; eight in rows 2, 3, and 4, and six in rows 5 ,6 and 7.

Ps. = *Psylla*; W.M. = Winter Moth; Ar. = *Anuraphis roseus*; Rp. = *Rhopalosiphum prunifoliæ;* W.A. = Woolly Aphis; Cap. = Capsids; Tort = Tortrices; Cole = *Coleophora nigricella.*

Total insects and Aphid colonies on four control trees = 1,518.

Total insects and Aphid colonies on 42 sprayed trees = 527.

The counts were made on the lower branches of the trees, but attacks of Aphis and Winter Moth were seen to be the same above as below. The sprayed trees were practically clean.

Summary.—The general effect of these two washes—Mortegg and Abolene—was very marked.

Psylla mali was completely controlled by 7½ per cent. and 5 per cent. washes, and the two species of Apple Aphides—*Anuraphis roseus* and *Rhopalosiphum prunifoliæ* -were practically so. Woolly Aphis here was much reduced, there being ninety-one patches on the four counted controls and only eighty-four on the forty-two sprayed trees.

Winter Moth on the sprayed trees showed a marked reduction, but by no means a definite control, there being fifty-seven on the four controls to 121 on the forty-two sprayed trees.

At 5 per cent. the effect was very little less than at 7½ per cent. *Coleophora nigricella* was not at all affected, nor, as far as one could judge from the small numbers present, was the Gold Tail Moth. Vapourer Moth eggs were all killed.

A certain amount of Mussel Scale and Brown Scale was completely killed. Capsids were too few in number to show any definite effect, nineteen being found on the controls and 108 on the forty-two sprayed trees. Red Spider was present to a small extent and as usual was not lessened at all.

The washes had a very good cleansing effect and there was little to choose between them. The orchard was so far cleaned that no spring spraying for insects was necessary. Scab, however, was bad.

3. At Wye.

Thirty-eight Worcesters and Newtons were sprayed on the South-Eastern Agricultural College Farms with Mortegg, Abolene and Carbokrimp. The trees were old and in an unhealthy state. A large number of ova of *Anuraphis roseus* and *Rhopalosiphum prunifoliæ* were found on them in winter. There was also in the previous year a rather heavy infestation of Woolly Aphis. Very few Psylla were present and no trace of Winter Moth eggs. In fact with the exception of Aphis this plantation was free from all insects. The plantation had been pigged for three years, and growth was very sappy. The controls were left in lines and in large blocks. All three washes were put on under Mr. Piper's charge at 10 per cent. strength, between February 7th and 10th.

The unsprayed parts and line controls early exhibited a rather severe attack of *R. prunifoliæ*. None was seen on the sprayed trees.

On May 18th an examination showed much *Anuraphis roseus* on all the controls, but only one or two here and there on the sprayed trees. By June 10th a heavy attack of Blue Bug developed on the controls. By the 15th a few *alatæ* commenced to appear and flew away from the dying spurs and shoots. A rough count at this time showed that 70 per cent. of the shoots and spurs on the controls were crippled. From this date onwards the blight increased on the controls, but the sprayed trees remained clean, or practically so.

On July 4th Mr. Martin Austin and the writer made a final count, taking four typical trees in each plot.

The following figures give a general idea of the Blue Bug presence on the whole treated and control trees :

Control 1	318	297	284	289
Mortegg	3	6	14	15
Control 2	378	288	302	323
Abolene	20	2	2	18
Control 3	140	321	306	397
Carbokrimp ..	22	2	3	13
Control 4	290	370	301	281

On one unsprayed tree, on a plot opposite the trial area, no less than 600 points of attack were counted, only twelve shoots being clean. It was noticed that the affected parts of the sprayed trees were those adjoining the controls.

Woolly Aphis was absent from the sprayed trees except one, whilst many of the controls were heavily infested.

Summary.—This experiment showed very definitely that all three Tar Distillates controlled the two species of Aphides, *Anuraphis roseus* and *Rhopalosiphum prunifoliæ* and also the Woolly Aphis. No other insect pests were present.

It may be pointed out here that a plantation separated only by a roadway, which had not been pigged or sprayed with Tar Distillates in 1928, was practically free from Aphis attack. There is no doubt that pigging encourages a sappy growth which is suitable for Aphis development and increase. The writer has always noticed that an excess of nitrogenous manure will encourage the attacks of Plant Lice; and that potash counteracts this.

4. AT BEARSTED.

At Mr. Bradley's Rose Acre Farm at Bearsted ninety-three apple trees were sprayed with Abolene, thirty-four with " Voss " Tar Distillate and the remainder with MacDougall's Wash.

The trees were standard Bramleys and Grenadiers, about twenty-three years old, planted 24 feet by 24 feet. The spraying was done from February 18th to 20th during excellent weather. Meyer's patent Spray Guns were used, the pressure being 100 lb. to the square inch and the size of the jet 2.5 mm.

All the trees were heavily infested with *Psylla* eggs; and very little else except Woolly Aphis was noticed. Unfortunately no controls were left.

On visiting this plantation on June 25th beating revealed very few *Psylla*. The counts were thirty-five and fifteen on eight trees of two rows sprayed with Abolene; eighteen on eight smaller Grenadiers sprayed with " Voss " spray and twenty-four on the Grenadiers sprayed with MacDougall with thirty on another eight trees. The trees were too high to take a complete count, only the lower branches being beaten. All the plantation seemed to be in the same comparatively clean state. The only insects in abundance were Yellow Leaf Hoppers (*Chlorita spp.*) which flew out in crowds when the branches were jarred, but not much mottling of the leaves could be seen. Woolly Aphis still occurred; twenty-five patches were counted on eight Abolene sprayed trees, thirteen on another eight, thirteen on eight treated with " Voss " and twenty-four on eight sprayed with MacDougall's Wash. From an examination much of this Woolly Aphis infection was seen to come from the roots. All three washes had thoroughly cleaned the trees and controlled the *Psylla*.

5. ON COB NUTS.

A plantation of Cob Nuts at Otham belonging to Mr. W. Chambers, of Greenhill House, Otham, over 100 years old but in full bearing, which was very foul with moss and lichens was sprayed with various Tar Distillates to see if nuts could safely be sprayed with these washes. The margin of time for so doing is

very small, owing to the early appearance of the male catkins and female flower buds. Another object was to clean up the trees and to see if there was any effect on the commoner nut-feeding insects.

It was not considered advisable to spray later than the time when the male catkins were in the stage shown in the figure, viz., January 6th. The female buds were at this time just beginning to get soft. The sprayed male catkins gave out their pollen normally some little while after spraying. No damage was done and the foliage of the trees looked much better than the controls. All the washes cleaned the trees satisfactorily, in spite of their very dirty condition. The weather during and after spraying was excellent. An examination of the plantation was made twice previous to spraying and a good many Aphis eggs were observed and some Winter Moth ova and a little Brown Scale (*Lecanium coryli*). Here and there the catkins were infested with the Cecid, *Contarinia coryli*. The washes used were Mortegg at $7\frac{1}{2}$ per cent. ; Carbokrimp at 6 per cent. and Abolene one at $7\frac{1}{2}$ per cent. and 5 per cent. and Abolene two at 6 per cent. and 3 per cent. Control rows and individual trees in each row were left. The washes were thoroughly put on by a hand pump at about 200 lb. pressure. The trees were especially well wetted owing to the amount of moss, etc. in the forks. In all, 128 trees were sprayed.

Numerous examinations were made from April onwards, the last on June 20th. At this time the whole plantation was found to be heavily infested with two species of Aphides, the commoner being *Myzocallis coryli*, which covered the under surface of the leaves. The other species was *Myzus avellanæ* which especially attacked the leaf petioles and the strigs of the young nuts. Where the latter species had settled the top of the young nuts had turned brown. At this time both species were becoming winged. A considerable amount of Cuckoo Spit, a sprinkling of Winter Moth and a few Leaf-rolling Tortrix occurred.

A careful examination showed very little difference between the sprayed rows and the controls, as far as the two species of Aphides are concerned. A number of counts of Aphides were made but the numbers varied so much on each tree and in each row, that the figures are considered to be of little value.

Only leaves with a number of Plant Lice on them were counted. The following is a selection of counts of Aphis attacked leaves on three trees :

A Control Row ..	290	480	760
Mortegg	301	604	90
Carbokrimp	504	239	240
Abolene I., $7\frac{1}{2}$% ..	205	605	640
Abolene II., 3% ..	605	171	194

Fig. 1.
Male Catkins of Cob Nut at time of Spraying.

Counts of Winter Moth larvæ (A) and Tortrix larvæ (B) on single rows:—

Control	A.470	B.75
Carbokrimp	A.145	B.10
Abolene I., 7½%	A.107	B.14
Mortegg	A.129	B.22
Abolene II., 3%	A.204	B.24

Leaves eaten by Winter Moth and leaves rolled and eaten by Tortrix were counted on each tree.

Summary.—It appears that none of the Tar Distillates destroyed the Aphis ova on the nuts. *Myzocallis coryli* certainly oviposits on the nuts, *sexuales* occurring in October. Whether *Myzus avellanæ* does so the writer is unaware, presumably this is the case as Stem Mothers were found on the trees early in May.

The effect of Tar Distillates on Aphis eggs is usually so marked and so persistent that it is strange that in this case no benefit resulted.

A considerable amount of reduction took place with Winter Moth and Tortrix and some Brown Scale present was quite destroyed.

All the washes cleaned the trees equally well, and the foliage in spite of Aphis attack looked much better on the sprayed trees.

It is hoped to try 10 per cent. solutions on these trees in 1929.

At all the centres the various brands of Tar Distillates used proved equally effectual.

TAR DISTILLATE TRIALS FOR CAPSID BUGS.

PART II.

Spraying trials were made during February and March, 1928, with various Tar Distillates to test their efficiency as a control for Capsid Bugs.

The trials were made at Sompting Manor near Worthing on a plantation belonging to Mr. Pullen-Bury and at South Street near Selling on a plantation and orchard belonging to Sir Walter Berry. At both places the trials were made in connection with the Apple Capsid (*Plesiocoris rugicollis*) and at South Street for the Currant Capsid (*Lygus pabulinus*). The results of these experiments are recorded here.

AT SOMPTING.

Here ten rows of Lane's Prince Albert, each of twenty-eight bush trees, were sprayed under Mr. Costin's supervision, between February 6th-9th. The

weather was fine at the time of spraying but a strong wind blew across the plantation and consequently some of the spray blew on to the rows on one side—two of the control rows (1 and 5) getting a good deal of spray in this way; the two outer control rows (9 and 10) however received none of the spray. The plantation for some years had been very badly attacked by Capsids—in fact the whole district around Sompting and Lancing is heavily infested and little fruit of value had been picked. The following were the washes used at Sompting:

Row 1, Control; 2, Carbokrimp; 3, Abolene;
4, Mortegg; 5, Control; 6, Carbokrimp;
7, Abolene; 8, Mortegg; 9 and 10, Controls.

The washes were all used on apples at 10 per cent. strength at both places.

At Sompting they were put on with a Drake & Fletcher sprayer at 100 lbs. pressure, and the weather was fine afterwards. The plantation was examined on April 4th and again on the 27th—the following rough notes being made on the foliage damage:

TABLE I.

Row.	Spray.	April 4th.	April 27th.
1	Control	Badly marked.	Bad, worse than on 4th.
2	Carbokrimp	Puncturing slight.	Slight, but increased.
3	Abolene	Puncturing slight.	Negligible.
4	Mortegg	Puncturing slight; more than 2 and 3.	Moderate, no increase apparent.
5	Control	Puncturing bad to moderate.	Bad. Considerable increase.
6	Carbokrimp	Puncturing slight.	Slight increase.
7	Abolene	Puncturing very slight.	Negligible, no increase.
8	Mortegg	Puncturing very slight.	Slight increase.
9	Control	Puncturing very bad.	Very bad, nearly every leaf.
10	Control	Puncturing very bad.	Very bad, nearly every leaf.

On June 1st and 2nd I visited the plantation again and made a detailed count of the damaged foliage on eight trees in each row and also Aphid and Winter Moth damage. The only other insect present was the Gold Tail Moth (*Leucoma chrysorrhœa*), the caterpillars of which occurred in considerable numbers on the controls, but only half a dozen on the six rows of treated trees.

The detailed counts are recorded below. The effect of the Tar Distillates in saving the foliage was very marked and is clearly shown in the photographs here of row 9 and row 8. (Figs. 2 and 3).

Photo by Walter Gardiner, Worthing.

FIG. 2.

Control row 9. At Sompting. Showing crippled foliage due to Capsid attack.

Photo by Walter Gardiner, Worthing.

Fig. [illegible]

Row 8. At Sompting. Mortegg sprayed. Showing normal leaf growth.

TABLE II.

Capsids Damaged Foliage.

Row.										Total.	Aphides.	Winter Moth.
1	Control	40	38	58	90	54	62	71	169	580	58	17
2	Carbokrimp	12	18	10	18	15	17	9	25	127	12	4
3	Abolene	10	19	14	20	7	19	12	19	120	14	2
4	Mortegg	19	7	15	22	10	17	14	12	116	10	12
5	Control	56	90	45	92	59	141	54	39	576	39	39
6	Carbokrimp	28	12	18	46	21	24	17	25	191	11	2
7	Abolene	22	30	11	12	17	14	11	30	147	17	4
8	Mortegg	40	40	38	31	17	25	30	32	253	10	14
9	Control	179	205	207	309	175	204	305	305	1889	159	59
10	Control	100	200	204	270	240	292	291	201	1888	170	75

On September 19th and 20th the crop was picked. Seven trees in each row were gathered by Mr. Costin and myself. Later Mr. Costin sorted and weighed the crop. The Table below gives the actual amounts of saleable fruit, capsid damaged fruit, and fruit damaged by other agencies, such as Aphis, Wasps, Scab, Brown Rot, Birds and badly bruised apples. More than half the saleable fruit

TABLE III.

Weight in lbs.

Row.	Saleable.	Capsid Damage.	Weight in lbs. Other Damage.	Total.	Spray.
1	47½	39½	28	115	Nil.
2	125	94	40	259	Carbokrimp.
3	187	50½	37½	275	Abolene.
4	183¼	75	37	295½	Mortegg.
5	59½	61	39½	160	Nil.
6	137	67	99	303	Carbokrimp.
7	190	69	26	285	Abolene.
8	128½	161½	52	342	Mortegg.
9	14	19	25½	58½	Nil.
10		Similar.			

was of large size and perfectly clean, the other half was smaller and some showed slight capsid damage, but not enough to spoil its commercial value ; the greatest scarring being three-quarters of an inch on any fruit.

A block of Lane's close to the trial plot was well sprayed by Mr. Pullen-Bury with hot lime. On examining this plot in June the foliage was seen to be much less damaged by Capsids than the controls. In two rows counted, of eight trees each—the damaged leaf areas were 174 and 170 against 1,789 and 1,888 in the two nearest controls. In spite of this it was seen during a visit in July that at least 90 per cent. of the fruitlets were scarred, very many had fallen, and at picking time most were valueless just as on the control rows 9 and 10 and in spite of the fact that at first the foliage looked healthy nearly all had by early August shrivelled up on these lime sprayed trees.

The beneficial result of Tar Distillate spraying was seen here to be very marked.

At South Street. (Apples.)

Here sixty-four King Edwards which had every fruit of a heavy crop so badly damaged by Capsids in 1927 that nothing was picked were sprayed on February 3rd, 1928. In 1927 it had been sprayed with 6 per cent. Mortegg and the fruit was all valueless. The next plantation of Newtons was that year sprayed with 10 per cent. Mortegg and the crop was a heavy clean one. A power sprayer was used at 200 lbs. pressure. The weather was fine but there was a strong head wind that made spraying one way a difficult matter. A valve defect reduced the pressure considerably when the last row (Row 1) was done. Rows 2 and 4 were sprayed a second time on March 12th. Row 2 has three trees sprayed with Abolene and four with MacDougall. Row 4 had four trees sprayed with Mortegg. These two rows certainly showed improvement, the saleable fruit in 2 being 59¾ lbs. and in 4, 93 lbs., but the Abolene Row 5 sprayed once nearly equalled Row 2.

Foliage damage was counted on April 4th and again on the 18th—not only for Capsid damage but also for Aphis and Winter Moth, the result being shown in Table below. The counts were made of the lower tiers of branches, the trees being too high to deal with the tops. The first Capsid count was made by Mr. Fryer and myself, the Capsid damage being very similar to that counted on the 18th. Another count made two weeks later showed little increase of leaf marking, just as was noticed at Sompting.

Rows 1, 3, 5 and 7 were affected by the strong head wind when spraying.

There was a very poor set of fruit. An early count of the damage to the small fruitlets showed that 5 per cent. only of the control row were not attacked, whilst on Rows 2 and 5 had at that time 80 per cent. and 64 per cent. clean (counts on two trees only in each row). Two weeks later this was reduced to 30 per cent.

TABLE IV.

Row	Wash.	Capsid Leaf Damage.	Aphides.	Winter Moth.
1	MacDougall	41	2	11
2	MacDougall	6	0	14
3	Mortegg	30	12	12
4	Mortegg	4	1	6
5	Abolene	24	0	14
6	Control	307	59	36
7	Carbokrimp	30	0	12
8	Carbokrimp	12	0	0

and 24 per cent., showing that the few fruitlets were sought after by the few insects that had hatched. This damage was evidently continued, judging from the results shown in the picking. The few apples picked were graded into saleable, Capsid damaged and other damage as shown below. The saleable ones included fruit with less than three-quarters of an inch scarring on any apple. The benefit of the Tar Distillates here was not nearly so great as at Sompting, owing to the small amount of fruit that set, the reduced number of capsids still not having sufficient fruit to feed upon. It may be noticed here that the Newtons nearest the treated plantation had here and there become infected again, whilst the trees twenty yards away showed no signs of Capsid presence.

The fruit was picked on September 4th and 5th and was graded by Mr. Martin Austin and Mr. Edenden ; the following being the weight in pounds.

TABLE V.

Result of Crop.

Row	Wash.	Saleable.	Capsid.	Other Damage.	Total lbs.
1	MacDougall ..	21½	103	3½	128*
2	MacDougall ..	59¾	151	12	222¾
3	Mortegg	59½	117	8¼	184¾
4	Mortegg	93	149	11¾	253¾
5	Abolene	57½	119½	7	184
6	Control	8¾	108	2¼	119
7	Carbokrimp ..	53¾	93½	5	152¼
8	Carbokrimp ..	52½	151	6½	210

* Note this row was affected by valve trouble.

On Black Currants.

A large plantation of Sir Walter Berry's at South Street which had been badly damaged by Capsids in 1927 was used for a Tar Distillate trial to see if any control could be obtained. Eight rows were sprayed, of seventy-two bushes each, on February 2nd, the washes used were the same as for the King Edward apples and the same power sprayer was employed. The washes were put on in fine weather and dried on well. All the washes were used at 6 per cent. strength and the bushes were thoroughly well wetted. The damage done by Capsids was very severe in most of the sprayed bushes, and the washes as seen by the following Table had no effect. Aphid centres of attack and the actual number of Winter Moth and Tortrix Moth larvæ were also counted. The aphides were completely controlled. The remainder of the large plantation was sprayed with MacDougall's Tar Wash by Mr. Berry and, as with the trial rows, was badly damaged by the Capsids. In the counts all the attacked bushes had more than two-thirds of the foliage damaged.

Table VI.

Result on Black Currants.

Row.	Wash.	Capsid Infested Bushes.	Aphides.	Winter Moth and Tortrix.
1	Abolene	52	0	7
2	Abolene	59	1	4
3	Mortegg	49	0	6
4	Mortegg	53	0	1
5	Carbokrimp	62	0	12
6	Carbokrimp	61	0	2
7	MacDougall	64	0	7
8	MacDougall	60	0	10
9	Control	61	25	30

There was little fruit in this plantation which was severely hit by two hard frosts and snow, which killed most of the blossom.

Summary.

It will be seen by the previous figures that the Tar Distillates both at Sompting and at South Street materially lessened leaf damage in the apples, clearly shown in the photographs reproduced here.

In the summer the growth of foliage was still more marked and wood was well formed whilst in the controls no growth took place at all. The effect on the fruit both in quality and actual weight was very marked at Sompting. At South Street it was less so, owing to the small amount of fruit that set, the little that was left being greedily sought after by the much reduced number of Capsids. Trees sprayed twice at South Street showed an improvement over those sprayed once.

With Currants the washes at 6 per cent. proved to be of no value in controlling the *Lygus* at all, but they acted, as elsewhere, as a definite check to Aphis. All four brands used in these experiments proved equally good (I could detect no difference between them).

A DISEASE OF THE STRAWBERRY PLANT.

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In 1925, *Diplodina lycopersici* (Cooke) Hollos emend, Brooks and Searle,* was found causing a disease of Strawberry plants under glass. Since then further reports of the disease have been received in view of which the following investigation was made.

Disease Symptoms.

The first symptoms usually appear at the base of the leaf petioles, where the tissues become almost black and finally collapse, causing the leaf to fall to the ground and die (Plate I., Figs. 1 and 2). The fungus grows rapidly within affected tissues but spreads slowly to neighbouring leaves, and hence a diseased plant frequently possesses a healthy centre surrounded by diseased leaves. Such plants are very liable to be overlooked and remain centres of infection. The root system may be attacked, but disease symptoms are only evident in young roots. These turn brown, shrivel, and die. New roots are sometimes formed higher up the crown and help to sustain the stunted plant. Inoculations showed that while the crown is very resistant, the flowers are extremely susceptible, but, as is shown later, it is improbable that the latter are attacked by the fungus under natural conditions.

Isolation of Fungus and Proof of Pathogenicity.

D. lycopersici was isolated from petioles of diseased plants in 1925, and subsequent inoculations and re-isolations proved conclusively that it was the causal organism. During 1926 and 1927 further diseased plants received from growers were examined, and in every case the fungus was present. In one case, where the plants had been grown in the open, abundant pycnidia were present in the petioles, roots, and flower stalks.

In 1927, a strain of *D. lycopersici*, isolated from diseased tomato fruits, was inoculated into healthy Strawberry plants and stems of tomato plants. Typical symptoms of the disease under investigation developed on the Strawberry plants, while on tomato plants a collapse of the tissues, reminiscent of the old tomato canker (*Diplodina lycopersici*), took place.

The Fungus.

The fungus conforms to the description given by Brooks and Searle except that the spores are smaller (average $6.4\mu \times 2.8\mu$). Usually less than 5 per cent.

* Brooks, F. T., and Searle, G. O. An investigation of some Tomato Diseases. Trans. Brit. Myc. Soc., vii., III. (1921), p. 173.

of the spores are mono-septate. It readily attacked green and ripe tomato fruits, and produced a canker of the stems of tomato, cucumber, and tobacco plants.

In pure culture on a synthetic medium* at temperatures ranging from 12.5° to 30°C., quickest growth occurred at 22° to 25°C.; growth occurred at 12.5°C. but was almost negligible at 30°C. The colony was dark brown at 25° and 27°C. and became less brown with decreasing temperature. Further pure culture studies showed that the colony remained hyaline on Coons medium, starch agar, and potato agar made alkaline with sodium hydroxide, while on Czapek's medium, and potato agar acidified with lactic acid, it turned dark brown. Abundant pycnidia developed on Coons medium.

Mycelial growth and pycnidial formation occurred on sterilised soil, undecomposed straw, and stable manure.

The optimum temperature for spore germination in hanging drop cultures was 22° to 25°C., at which temperatures germination commenced in six hours. Germination occurred at 12.5°C., but at 28° and 30°C. it was rare and sometimes the spores swelled enormously and each produced several germ tubes.

INOCULATION EXPERIMENTS.

MODE OF INFECTION.

Preliminary experiments were made to determine those parts of the plant susceptible to attack. Pieces of mycelium from pure cultures were inoculated into leaf petioles, young leaf buds, roots, flower stalks, crown, stolons, and green and ripe fruits. Plants were kept in moist chambers in the laboratory, and where possible, wounds were covered with tinfoil. All parts proved susceptible except the crown and, in some cases, stolons.

In another series of experiments infection occurred when pieces of pure cultures were placed in contact with leaf petioles and blades, roots, flowers and fruits.

The above experiments showed that the disease may attack almost any part of the plant and further experiments were necessary to ascertain the mode of infection under natural conditions.

Strawberry plants and detached leaves in moist chambers at different temperatures, were sprayed with a heavy suspension of spores in water. Spores were obtained from pure cultures or diseased tissue, and their viability tested in hanging drop cultures. Flowers were killed in a few days (Plate II., Fig. 3) and leaf stipules were frequently infected, but the leaf blades remained healthy except in comparatively few cases. This was probably due to the hairy covering which caused most of the spore suspension to run off. Where infection occurred,

* Glucose	20.0 grams.	$Mg.SO_4$	0.75 grams.
Asparagin	2.0 ,,	Agar	15.0 ,,
K_2HPO_4	1.25 ,,	Water	1000 cc.

well defined, dark brown, spots appeared (Plate II., Fig. 4) which gradually extended over the whole lamina and sometimes grew into the petiole. Numerous pycnidia developed in the diseased tissues.

Many experiments were made, and from the results obtained it was concluded that direct infection of aerial parts by spores is a very remote possibility under natural conditions, and that the spores usually pass to the soil and spread infection in this manner. In this connection it may be stated that inoculations of sterile soil and stable manure with spore suspensions gave rise to mycelial growth.

To ascertain if the disease originates where the tissues are in contact with contaminated soil, plants were set in moist soil previously infected with pure cultures of the fungus. At first no disease appeared on the leaf petioles, but in later experiments, in which plants were set so as to ensure intimate contact between the soil and leaf petioles, typical disease symptoms developed in the latter. When the soil was kept very moist, whole leaves were killed in seven days and abundant pycnidia formed in the tissues. Controls remained healthy. It appeared during these experiments that the fungus was favoured by wet conditions round the base of the plant. Examination of the roots showed that some of these were infected, but new healthy roots were usually present higher up the crown. If planted so that only the crown and root system were touching the soil, plants continued to live and did not appear to suffer greatly as regards vegetative development. It was not possible to compare the yield of such plants with that of plants growing in clean soil.

The conclusions drawn from these experiments were that the disease originates through contact with soil infected with *D. lycopersici*, and that deep planting, by bringing the petioles in contact with the soil, causes rapid development of the disease.

Temperature Relations.

It appeared during the course of the work that the disease developed more readily under cool conditions, and so experiments were made to test this. Plants were set deeply in moist infected soil, and placed in positions of different average temperatures. So far as was possible other conditions were kept constant. Infection occurred between 3.3° and 23.0°C., but, as judged by the number and extent of the diseased petioles, was most severe about 15°C. Reports indicate that under glass the disease appears in Spring or late Summer.

Overwintering of the Fungus.

The fungus grew and formed pycnidia in sterile soil, straw, and stable manure. The cultures were placed outside in September and examined the following March, when it was seen, by transferring spores and mycelium to culture media or water, that the fungus was quite active. Thus the disease may be

Fig. 1.
Photograph taken eight days after inoculation, showing two infected and two healthy control leaves.

Fig. 2.
Surface aspect of Fig. 1.

PLATE I.

FIG. 3.

Control and infected flowers respectively. The latter were inoculated with a spore suspension and photographed seven days later. Note the disease passing into the flower stalk at A

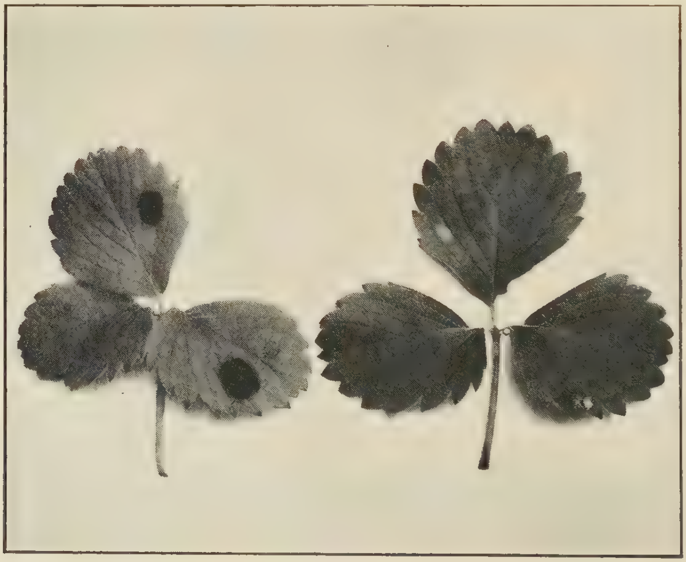

FIG. 4.

Showing an infected and control leaf respectively. The former was sprayed with a spore suspension and kept in a moist chamber at 20°C. Photograph taken six days after inoculation.

PLATE II.

introduced and spread by the use of contaminated soil, straw, or stable manure. It was also shown that the fungus could pass the winter on diseased Strawberry tissue in the soil.

Soil Sterilisation.

From facts elicited during the investigation it was evident that control measures must be based on soil sterilisation. So far as the work has proceeded sterilisation by heat is the only means of eradicating the disease. Heavily infected soil was steamed for half an hour or baked for one hour at 95°C. and plants grown in it remained healthy, while controls were severely diseased.

Efforts to find a fungicide suitable for outdoor application were not successful. Plants were set in infected soil and treated with copper sulphate (1.0 and 0.4 per cent. solution), Cheshunt compound (0.32 per cent. solution), and Uspulun (0.25 per cent. solution), but in no case was the soil freed from disease.

Control Methods.

1. After a season of disease soil sterilisation is necessary if the next crop is to remain healthy. Where possible heat sterilisation should be carried out.
2. Deep planting and excessive moisture round the base of the plant are particularly liable to favour the disease and should be avoided.
3. As the fungus can overwinter on diseased tissue and straw, these should be destroyed. The practice of using the same straw in consecutive years is dangerous.
4. Young plants should be taken from clean stocks and diseased plants should be destroyed at once.

The Author wishes to express his sincere thanks to Dr. W. F. Bewley for advice and criticism during the investigation. The photographs shown in Plates I. and II. were taken by Mr. W. Corbett, to whom thanks are due.

Summary.

1. *Diplodina lycopersici* has been found causing a disease of the Strawberry plant under glass and in the open.
2. Cross inoculations showed that the fungus caused a canker of the stems of tomato, cucumber, and tobacco plants. Inoculations of Strawberry plants with a strain of *D. lycopersici* isolated from diseased tomato fruits, caused symptoms of the Strawberry disease to appear.
3. All parts of the plant, except the crown, are very susceptible, but infection usually occurs in those parts in contact with the soil. The soil is the chief source of infection.
4. Deep planting, and cool, wet conditions favour the disease.
5. Control methods are suggested.

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THE BEHAVIOUR OF CERTAIN PEARS ON VARIOUS QUINCE ROOTSTOCKS.

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In Volume XLV. of Journal of the Royal Horticultural Society (1) there are described and figured five varieties of Quince. Four of these, designated Types A, B, C and D because their accurate nomenclature was in considerable doubt, were readily distinguishable from one another by characters of bud break, leaf, and habit of growth, amongst the not infrequently mixed samples of Quince rootstocks in commercial circulation. The fifth, Type E, purporting to be the Portugal, represented a more vigorous group of larger leaved varieties, with which the so-called Apple-shaped Type F and Pear-shaped Type G were then grouped. These three varieties were included in the experiments there outlined, not because there was any evidence of their present use as rootstocks for Pears, but since old horticultural tradition said that these more vigorous types would impart their vigour to the scions grafted thereon.

This collection in no way claimed to be exhaustive, for, as stated in 1920, at least three other variations from the four main types (A, B, C and D) had been detected and isolated from commercial samples. But since these " sub-types " appeared in very small numbers, they were planted in an arboretum for reference and were not dealt with until later. In the case of the main varieties, on the other hand, vegetatively propagated races were immediately raised, not, perhaps unfortunately, from a single type plant from which the initial botanical description had been made, but from what appeared to be in each case the truest commercial strain, which had been previously subjected to careful roguing on botanical and other characters. Whilst there is no reason to doubt that each of these races originated from a single parent, it is impossible to prove, and therefore it is felt that the records collected from such material do not warrant the drawing of too fine distinctions. If clones, raised only from the described type plant, had been available then, as they are to-day, certain cases of the exceptional behaviour of individual trees worked upon these rootstocks would have been worth discussing in more detail. However the comparative results obtained from using even this material in an investigation of rootstocks for Pears are sufficiently significant to justify chronicling at this juncture.

Unfortunately, the nomenclature of the Quince root stocks is no clearer than it was in 1920, and the writer finds it impossible to depart from the lettering then given, because he is fully aware that the " Angers " of one district is still the " Common " of another, and the " Fontenay " of a third.

The situation is lamentable, as this paper will demonstrate, but for present purposes it must suffice to abide by the descriptions and designations of the rootstocks to be compared as they were detailed in the aforementioned paper.

Type A forms the bulk of most English stoolbeds and is undoubtedly in most common circulation—sometimes true to type, often intermixed with Types B and D, and occasionally with a few Type C's. The very general concensus of opinion would agree that this stock is the true Angers Quince. However, it is the " Fontenay " of some.

Type B is fairly commonly met with, and like A it is sometimes true, sometimes mixed. It is variously called " Common," " Angers," and merely " Quince."

Type C is by far the least common, and it appears no longer to exist even at the source from which it originally came true to East Malling Research Station, under the name of Angers. It is very readily distinguishable by its compact upright growth and very yellow leaf in early spring.

Type D is equally easily distinguished by its exceptionally dark foliage and weeping habit. It is a frequent rogue amongst Types A and B, and has come from the Continent both under the names of " Fontenay " and " Common " Quince.

Types E, F and G, the Portugal, Apple, and Pear-shaped respectively, have already been referred to as belonging to a more vigorous group, for which reason they were selected for trial as rootstocks.

BEHAVIOUR IN THE NURSERY.

These seven varieties of Quince, described, rogued and vegetatively multiplied as already described, have now been submitted to the nursery test.

In the rootstock experiments with plums it has been shown that early symptoms of any " incompatibility;" betwixt stock and scion are more evident on budded than on grafted trees (2), hence it was decided, throughout these comparative tests, to use budding as the method of propagation. All the stocks used in the experiments were raised in the Station's own stoolbeds.

The first nursery bed, in 1920, consisted entirely of young Conference maidens budded in 1919 upon six of the Quince varieties, the difficulty at that time of raising Type E, Portugal, accounting for its absence. Twenty comparable stocks of each variety were budded, and in every case it was possible to draw out the unit of sixteen trees, with stems of over 2 feet, required for planting February 18th, 1921. Though there was thus no evidence of the failure of buds to " take," the average weight of the maiden trees at planting varied considerably according to the root stock—those on Quince Type A being outstandingly the heaviest, and those on Types D and F by far the lightest.

TABLE I.

Mean Heights and Weights of Conference Maidens (budded 1921), September, 1922.

	on	A	B	C	D	E	F	G
No. of Trees		50	50	50	50	11	25	25
Height	cm.	60 (s.e.=1.5)	63 (s.e.=1.3)	60 (s.e.=0.8)	56 (s.e.=1.6)	67 (s.e.=3.5)	63 (s.e.=2.2)	65 (s.e.=2.5)
No. of Trees		16	16	16	16	8	16	16
Weight	oz.	6.3(.3)	6.6(.2)	5.9(.3)	7.6(.3)	5.5(.3)	5.5(.4)	6.6(.3)

The second nursery plot, budded 1920, consisted of a comparative trial of Dr. Jules Guyot, Pitmaston Duchess and Durondeau on the complete series of Quince Types A to G, of Doyenne du Comice on Quinces A to E inclusive, and of Beurre Hardy on Quinces A, B and C only. In the cases of Dr. Jules Guyot and Durondeau there is evidence that Stocks D to G not only produced smaller trees, but that fewer buds were successful when inserted in E, F and G. There are also notes extant as to the frailty of the unions of these two varieties on these four rootstocks. In the case of Pitmaston Duchess, whilst D and G again produced small trees, E and F produced maidens comparable with A and B. The buds of Doyenne du Comice show a slight preference for Quinces A and B though the few maidens which grew on Quince E were as good as those on A.

The third nursery plot budded 1921, was designed to check more precisely the results of the first trial with Conference in 1920. Again, there is no striking evidence of any failure of buds to take, except possibly in the case of Quince E, for though Table I. shows a different number of trees produced, this is due in part to the variable number of certain rootstocks ultimately available for budding.

If, however, the weights of the Maidens are compared with those in the first experiment, whilst the trees on Quince F. are still the lightest, those on Quince D are now actually the heaviest. On the other hand, if the heights of the maidens are compared, the trees on Quince D. will be seen to be significantly shorter than all the others.

However, the nursery records for the 1921 budding season are the most complete, and show very distinctly that one rootstock throughout yielded comparatively poor results, i.e., Quince D, whilst others, E, F and G, gave poor results only when combined with particular varieties. Quinces A, B and C, yielded apparently satisfactory results with Conference, Fertility, Emile d'Heyst, Dr. Jules Guyot and Durondeau ; Quinces F and G with only the first three. Table II. shows this very clearly.

TABLE II.

Number of Buds taken in 1922-23 on various Quince Stocks. (Forty Buds of each variety on each Stock inserted 1922.)

Quince Variety :	A.	B.	C.	D.	E.	F.	G.
Pear Variety—							
Conference	38	37	38	21	23	36	33
Fertility	39	39	38	30	32	38	40
Emile d'Heyst	37	39	30	18	20*	35	35
Dr. Jules Guyot	38	34	36	17	19*	25	22
Durondeau	37	38	37	15	11*	31	27

* Only 30 buds were inserted in these cases.

The number of buds which "took" and grew, however, does not tell the whole story, which is carried a stage further by studying the average heights of the resulting maiden trees in Table III. Again the varietal aspect is emphasised. The Conference trees are fairly uniform on all stocks with the outstanding exceptions of those on Quinces D and E. Thus for the third time, an indication of the unsuitability of Quince D was obtained. Fertility falls off on Quinces E, F and G; Emile d'Heyst, giving a new combination of stock and scion, showed a marked preference for A and C, falling off especially on F and G, though the "take" of buds of this variety on those stocks did not in itself suggest any incompatibility. Dr. Jules Guyot, and Durondeau proved inferior on all four stocks, thus confirming the evidence from the second nursery.

TABLE III.

Average Heights in cm. of Resulting Maidens September, 1923.

Quince Variety:	A.	B.	C.	D.	E.	F.	G.
Conference	66	74	71	50	51	74	76
Fertility	104	106	104	102	84	99	99
Emile d'Heyst	89	75	81	71	71	66	64
Dr. Jules Guyot	64	66	64	30	41	43	41
Durondeau	99	104	102	63	33	66	71

Even the limited experiences of these four years consecutive nursery trial would seem to establish the following facts:—

(*a*) The seven Quince varieties may be roughly divided into two groups— A, B and C which it is comparatively safe to use from a nurseryman's point of view, and D, E, F and G which it would be unwise to use as rootstocks unless some very special reason were established in the case of particular varieties. Thus of the Quince varieties in common circulation as root stocks Type D has proved manifestly unsuitable, whereas the apparently little used Type C deserves more notice.

(*b*) Cutting across this generalisation, are two qualifications:—

First, that particular varieties evince distinct preferences for particular Quince stocks, occasionally even for the generally unsuitable ones.

Secondly, that peculiar seasonal conditions may cause a partial modification of the phenomena associated with incompatibility in the nursery, and at any rate mask for a time the effect of combinations which in less favourable seasons are undoubtedly unsuitable. This seems to suggest that in the case of the Pear, the part played by the actual union of each individual scion and stock may be a very vital one to the subsequent behaviour of the tree.

THE DIFFERENT ROOT SYSTEMS EXAMINED.

Some observations were made upon the character of the various root systems when the series of Conference maidens were planted in January, 1923, and again when the Fertility and other varieties were lifted in November of the same year.

The following notes embody the conclusions so far as the Conference maidens were concerned :—

On Quince A.—The coarse laterals averaged ten per tree : they were evenly distributed, and showed a slightly downward tendency.

There was a moderate amount of fine fibre from the less coarse laterals.

On Quince B.—The laterals, coarser than on A, averaged thirteen per tree ; they were evenly distributed, and showed more downward tendency. There was scarcely as much fibre as on A.

On Quince C.—The laterals, coarser than A or B, averaged thirteen, they were well distributed, but compact and growing almost straight down. There was much fibre from the less coarse laterals.

On Quince D.—The very coarse laterals averaged nine per tree ; they were on one side mostly, knotted, twisted and often growing upwards. There were few fine laterals and little fibre.

On Quince E.—The coarse laterals averaged eight ; they were twisted and on one side, knotted and often upturned. There were practically no fine laterals and very little fibre.

On Quince F.—The coarse laterals averaged six ; they were mainly towards the base, with downward tendency. There were very few fine laterals, and practically no fibre.

On Quince G.—The coarse laterals averaged seven ; they were mainly towards the base, often spreading. There were more fine laterals and more fibre than on D, E and F.

Although taken by another observer, the comparative notes on the similar root systems of the Fertility maidens were strikingly confirmatory—though all the root systems appeared to be rather better fibred. This was possibly due to the very vigorous maidens of this variety. When budded with Durondeau, Emile d'Heyst and Dr. Jules Guyot the various root systems appeared in the main to retain the general characteristics already described, though they were quantitatively weaker throughout, and, where definite incompatibilities were evident, the root systems were exceptionally weak.

Curiously enough, the whole series of Emile d'Heyst was singled out as having weak root systems, despite the fact that the maiden heights would

proclaim them a more vigorous series than either the Conference or Dr. Jules Guyot. Whilst the general similarity of the root systems of the different Quinces was striking throughout the series of five scion varieties, qualitative differences due to scion influences were not apparent.

Behaviour of the Trees in the Plantation.

The Plantings.—From the series of nursery trees already referred to, there have been made four successional plantings as follows :—

(i) On February 18th, 1921, sixteen maiden trees of Conference Pear were planted out on six varieties of Quince.

(ii) A year later, February, 1922, units of approximately eight trees of Pitmaston Duchess and Durondeau on each of the seven stocks, of Dr. Jules Guyot on six stocks, of Doyenne du Comice on five, and of Beurre Hardy on A, B and C were planted.

(iii) On January 23rd, 1923, a second planting of Conference Pears was made. The unit of trees was again sixteen and in this case Quince E (Portugal) was included.

(iv) On November 23rd, 1923, further trials were set out. Twenty trees of Fertility, an average of twelve trees of Emile d'Heyst, of eight trees of Durondeau, and varying numbers of Dr. Jules Guyot were planted on the complete series of seven stocks.

Thus, whilst it has been possible to watch the effect of the Quince stocks upon eight varieties of Pear, including most of the commercially grown sorts, it has further been possible to make a successional planting of three of them in order to check the results in different seasons.

At the time these trials were planted little attention had been given to correct methods of planning experimental plots, and the only arrangement then made was that of dividing each unit of trees on any one stock into at least two groups, with a view to including such factors as soil variability.

In all cases special effort has been made to standardise throughout all the cultural, pruning, manurial and spraying treatments, and it can confidently be stated that these essential operations have not proved to be disturbing factors to any extent.

On the other hand, the weather conditions in several seasons—notably in 1927 and 1928—have militated against the harvesting of representative crops of fruit. Indeed in some years the blossom has been so wind bruised that it never opened normally, whilst in others the fully formed fruits were to be seen hanging black upon the trees after frost.

RECORDS TAKEN.

Some individual tree records have been carried out annually on the vast majority of the 750 trees concerned in the experiment.

In order to obtain some comparative measure of vigour, in the earlier years measurements of the annual wood growth increments were taken. Later, the average height and spread of the tree, and the girth of the stem, have been substituted on the older trees. A count of the number of blossom trusses has been made where possible, first to try to investigate whether there was any difference in the percentage of flowers setting fruit on different rootstocks, and secondly to obtain some record of early precocity upon varieties on which the weather conditions already referred to had acted so adversely as to ruin the whole crop.

TABLE IV.

Subsequent Mortality in the Plantation of units of sixteen Conference Maidens Planted 1921.

	A.	B.	C.	D.	F.	G.
1st year (1921) ..	None	None.	None.	3	10	5
2nd year (1922) ..	—	—	—	0	6	8
3rd year (1923) ..	—	—	—	1	—	1
4th year (1924) ..	—	—	—	0	—	0
5th year (1925) ..	—	—	—	1	—	0
6th year (1926) ..	—	—	—	1	—	1
7th year (1927) ..	—	—	—	1	—	0
8th year (1928) ..	—	—	—	0	—	0
Total	None.	None.	None.	7	16	15

EVIDENCES OF INCOMPATIBILITY.

The first planting of Conference, the remaining trees of which are now nine years old, gave a somewhat startling and unexpected result. Although the maiden trees from the nursery showed some differences in actual weight, there was no reason to expect differences in their capacity to make trees. Table IV. shows what happened.

All the trees on A, B and C developed normally; those on D, F and G behaved very differently. Whilst those on F completely died out in the first two years, those on D have died much more slowly, often remaining stationary for several years before dying altogether. Even if this might have been expected from the rather slighter trees on D and F, it could not have been inferred from the fully representative maidens on Quince G, thirteen of which died in the first two years, only a solitary one remaining to-day.

The second planting of Conference, which was made two years later, has not produced quite the same dramatic results. On the other hand, the measurements

of total wood growth, see Table V., during the first five years demonstrate that the trees on D, E and F are much less vigorous than those on A, B and C, and at the same time the comparatively high standard errors on trees on D, E and F show that whilst some trees on these stocks are developing normally, others have already fallen far behind the mean—and one tree on D and one on E have already died out. Other trees exhibit a distinct discolouration in foliage, and there is reason to believe that many of these trees are progressively showing signs of incompatibility. The case of the trees on G in this second planting is a very curious one, since so far they have behaved quite normally.

Were it not for the fact that the dramatic results shown on the first series of Conference have since been repeated with four other varieties, Fertility, Dr. Jules Guyot, Emile d'Heyst and Durondeau, and in successive seasons, that planting might have been considered an exceptional one, possibly due to the dry weather conditions subsequent to planting in 1921.

In fact, the weight of evidence goes to prove that the behaviour of the second series is the more exceptional, and that possibly certain conditions were peculiarly favourable to the formation of good unions in that year, so that the full effects of incompatibility have been delayed or obscured.

TABLE V.

Second Planting of Conference Pear on Various Quince Stocks. Seven years.
(*Unit of trees* .16.)

Quince Variety	Total Wood Growth 5 years. Metres.	*S.E.*	Girths 1928. Mm.	*S.E.*	Height 1927-8. Metres.	*S.E.*	Spread.	*S.E.*
A.	48.65	(*2.41*)	144	(2.8)	2.24	(*0.03*)	0.91	(*0.02*)
B.	43.38	(*2.21*)	137	(3.8)	2.22	—	0.99	—
C.	43.17	(*1.34*)	144	(1.9)	2.08	(*0.02*)	0.97	(*0.02*)
*D.	33.48	(*3.71*)	130	(1.6)	2.08	—	0.80	—
*E.	39.56	(*5.31*)	127	(2.7)	2.05	—	0.81	—
F.	33.91	(*2.73*)	128	(5.3)	2.23	—	0.79	—
G.	45.37	(*1.61*)	148	(2.4)	2.23	—	0.89	—

* One Tree dead.

All the five varieties planted in 1921-22 established themselves satisfactorily on Quinces A, B and C. Only three varieties, Pitmaston Duchess, Durondeau and Doyenne du Comice, were worked on Quince D, and, as the wood measurements show (Table VI.), in no case have they produced half the growth which they have made on A, B and C. In addition to these three varieties, Dr. Jules Guyot was planted on Quince E, and all but Pitmaston Duchess exhibit abnormal dwarfingness ; Durondeau again behaves similarly on Types F and G, and

TABLE VI.

Wood Growth at five years of five Varieties on different Quince Stocks.

On Quince :	Total Wood Measurements. Means in Metres. (Average Unit of Trees 8).						
	A.	B.	C.	D.	E.	F.	G.
Pitmaston Duchess ..	42.0 (*S.E.2.9*)	56.2	52.1 (*S.E.3.0*)	9.4	42.3	69.7	69.4
Durondeau	49.0	53.1	57.3	16.0	10.7	5.9	5.0
Doyonne du Comice ..	30.3	34.8	41.1	12.6	9.3	—	—
Beurre Hardy	34.6	42.1	36.2	—	—	—	—
Dr. Jules Guyot ..	16.4	16.6	14.6	—	9.1	16.9	11.3

Dr. Jules Guyot on G, whilst Pitmaston appears to flourish exceptionally on these two stocks. There has again in this series of trees, in the cases of Durondeau and Dr. Jules Guyot, been considerable evidence of actual mortality. For instance, although the average wood measurements of Dr. Jules Guyot on F would suggest flourishing trees, actually two out of the eight trees have died out. On the other hand it must be remembered that this variety is reputed to be exceptionally unsuitable for working direct on Quince, and there have actually been casualties with Dr. Jules Guyot on Types B and C apparently quite healthy trees breaking out at the union. However, the second plantings of these two varieties, Durondeau and Dr. Jules Guyot, have fully confirmed the manifest unsuitability of Quinces D to G. The story has been one of progressive evidences of incompatibility—trees remaining completely stationary in growth, and eventually dying.

The history, from 1921-25 inclusive of eight trees of Durondeau on Quince G, planted out as an even set of maidens, well illustrates this type of behaviour of a variety upon one of these " incompatible " stocks.

Tree No. 1 made fairly normal growth in its first, second and third year. It practically stopped growth in the fourth. In the fifth, it started into strong growth again, a phenomenon which was attributed to the scion itself rooting. Investigation proved this to be the case.

Tree No. 2, whilst making fairly normal growth in the first and second year, fell off in the third, made no growth whatever in the fourth and died out in the fifth.

Tree No. 3 behaved almost identically with tree No. 1, though it made no new growth at all in the fourth year.

Tree No. 4 grew fairly regularly each season, but did not make the exceptional growth in the fifth year, due to scion rooting in Nos. 1 and 3.

Tree No. 5, after a good maiden growth, started away in the second year but was dead before the end.

Tree No. 6 made a little growth during the second and third year and has remained stationary since.

Tree No. 7 grew rather better the first three years, indeed it was the most vigorous tree of the series, in 1923, but in 1924 and 1925 it made no growth at all.

Tree No. 8 grew rather more vigorously than No. 6, and less so than No. 7, for the first three years, and then stopped growth completely.

Thus whilst two trees out of the eight died (one at the end of two years, and one at the end of five), three more ceased to make any growth for two successive seasons, two after stopping growth for one season are now forging ahead, and one, which has grown fairly normally for four years, is beginning to lag behind. Even the strongest of these trees (7.90 metres) is 50.00 metres behind the average for the same variety on a compatible rootstock such as Quince C.

All the remaining trees of Durondeau and Dr. Jules Guyot of the 1923 series on stocks D. and G. were removed from the plot in 1927, having all reached this stationary condition.

In the same series, Emile d'Heyst has exhibited similar symptoms, practically all the trees on E, F and G having died during the first five years ; the remnant of these, together with those on D, show a marked marginal blackening on the leaves in early autumn, suggesting possible starvation. This discolouration of the leaf margins has been noted to a lesser extent on other varieties budded upon Quinces D to G.

Should any further evidence of this incompatibility be necessary, it is found to be well illustrated in the mortality of a considerable series of Fertility on the complete range of quince stocks. At the time of planting the average weight of the maiden trees on stocks F and G was practically identical with that for the trees on A, B and C, only the trees on D and E being slightly less. As Table VII. shows, the trees on F and G have practically died out, except where the scion has managed to establish itself on its own roots. (See figs. 1 and 2). Whilst the mortality has been less in the case of E, and is absent from the trees worked on D, the variation in the individual total wood growths shows that many trees in this series are showing unmistakable signs of distress. The

TABLE VII.

Subsequent Mortality in the Plantation of twenty Fertility Maidens Planted 1923-24.

Quince Variety :	A.	B.	C.	D.	E.	F.	G.
2nd year (1925) ..	—	—	—	—	—	—	1
3rd year (1926) ..	—	—	—	—	1	1	2
4th year (1927) ..	—	—	—	—	5	7	6
5th year (1928) ..	—	—	1	—	1	5	6
Total	—	—	1*	—	7	13	15

* Healthy tree broken off at union by cultivator.

FIG. 1.

Fertility Pear—6 years—on Quince A, exhibiting normal growth.

FIG. 2.

Fertility Pear—6 years—on Quinces D and E, exhibiting different degrees of "incompatibility."

wood measurements of the trees on D vary from 7.59 to 26.67 metres and those on E from .9 to 18.8 metres, whilst the variation on a compatible stock such as A is only half as much. In other words, comparing the variability of Fertility trees on Types A and D by means of the statistical constant known as the coefficient of variation, whereas this coefficient for trees on A was 18 per cent. of the mean, for those on D it was just under 40 per cent.

Thus, the behaviour in the plantation of these eight varieties of Pear upon the range of quince stocks vastly strengthens the recommendations made upon the nursery indications. Although, in certain exceptional instances, apparently normal growth has been obtained on Quinces D to G, they must generally be regarded as quite unsuitable.

It remains then to compare the behaviour of these varieties upon Quinces A, B and C, which have so far shown no real evidence of incompatibility, except possibly in the case of Dr. Jules Guyot.

Vigour and Cropping of Normal Trees on Quinces A, B and C

A very interesting fact is revealed by a close study of the wood measurements of the eight varieties in the early years. With few exceptions, the figures to-day show no significant differences in the vigour of trees on A, B and C. See for instance Diagram (A) comparing the first five years' wood growth after planting, of the oldest series of Conference.

As shown in the Diagram of wood growth from year to year, the trees on Quince C were in the second year ahead of those on A and B, which were indistinguishable. In the third year, those on both A and C made significantly more growth than those on B. From this year onwards, the actual means of the wood growth of trees on A were slightly higher than those on C, but not sufficiently so to be significant in themselves. During the fourth and fifth year, the average wood measurements of trees on B were almost identical with those on C, but at the end of the five year period there was actually no significant difference in the growth on the three stocks, though the difference between A and B is sufficient to be very suggestive of a real effect.

TABLE VIII.

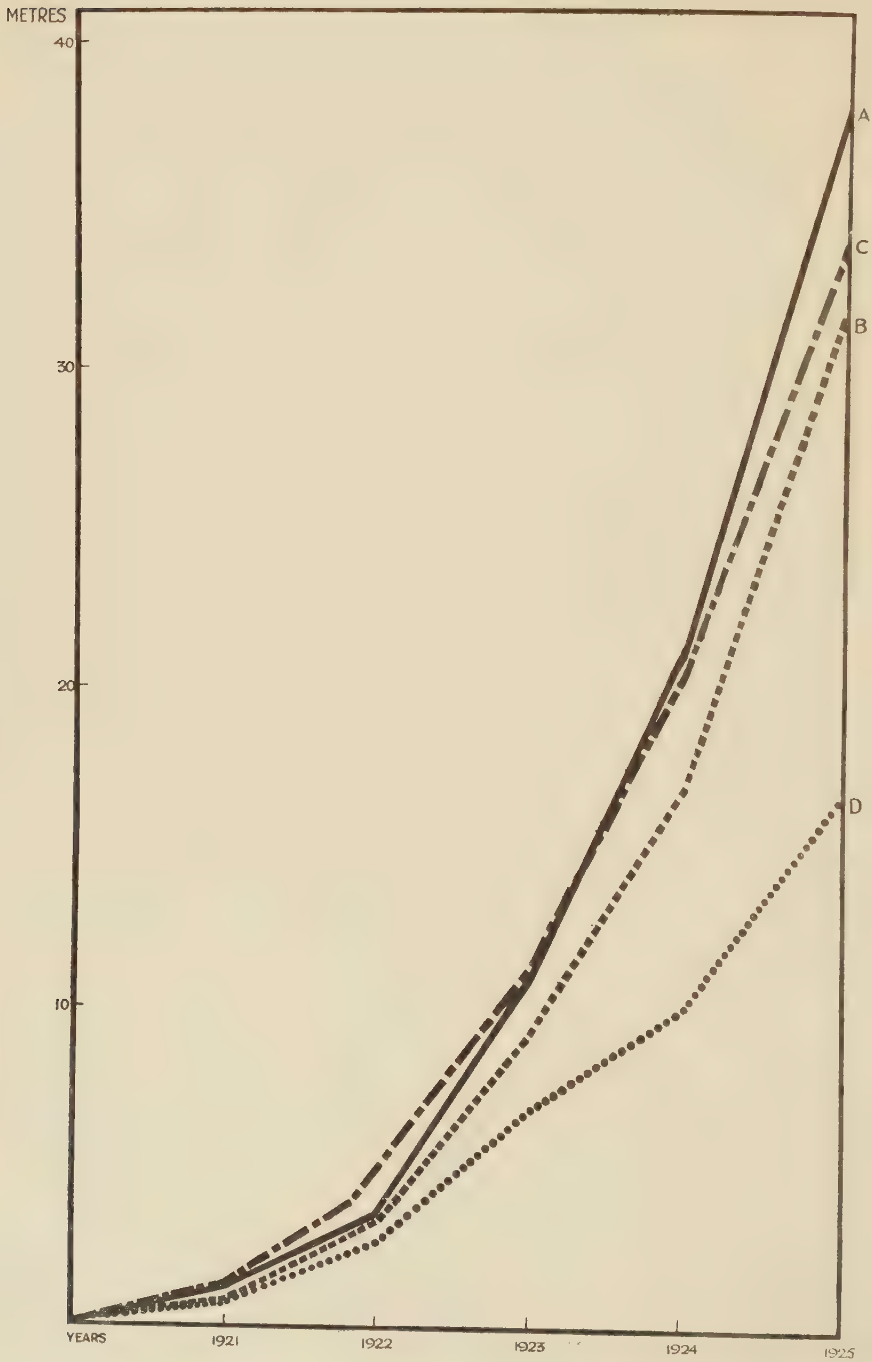
Vigour Measurements of Sixteen Conference Trees on Quince Varieties (nine years old).

	Total Wood Measurements. Mean per Tree, 1921–5.		Girth in mm. 1928.		Height in metres. 1927–8.		Spread in metres. 1927–8.	
	Metres.	*S.E.*		*S.E.*		*S.E.*		*S.E.*
Angers A. ..	37.8	*(2.23)*	198	*(5.98)*	2.79	*(.08)*	1.50	*(.044)*
Common B. ..	32.2	*(1.8)*	194	*(4.34)*	2.84	*(.04)*	1.39	*(.029)*
,, C. ..	35.0	*(1.79)*	190	*(2.51)*	2.57	*(.05)*	1.49	*(.025)*

DIAGRAM A.

CONFERENCE PEAR.

Average Wood Growth from year to year on Quinces A to D.



From 1925 wood measurements were discontinued, and it is only possible to judge the comparative vigour of these trees to-day from their girth measurements and heights and spreads given in Table VIII. The former show no significant differences at the beginning of 1928.

In the case of heights and spreads the only significant differences shown are that the trees on B are on the average significantly less spreading than those on A and C, whilst those on C are significantly less tall, and therefore appear more spreading.

It seems at least possible, therefore, that A has accentuated its slight lead over C in wood growth and that B has caught up A and C. The cause of this may not be unconnected with the fruiting record of the trees on these three stocks to be considered later.

This early lead in wood growth of trees on C is, if anything, accentuated in the second planting of Conference. At the end of the second year (1924) the trees on C averaged 1 metre more wood growth than those on A. Again, in the fourth year the trees on A began to gain and, by the end of the fifth year, are nearly 5 metres ahead of those on C, though owing to the amount of variation this difference is not significant. (Refer Table V.) At the end of the period, the height and spread measurements show, for the second time, that the trees on C are less tall and in this case actually more spreading than those on A.

The early vigour of trees on C is strikingly confirmed by the remaining varieties of the series. In the case of Fertility even up to the end of the fourth year there is a difference in favour of the trees on C, which is significant, in comparison with the averages of those on B and very nearly so with those on A. (See Table IX.) In the previous year, mean wood measurements of trees on C were significantly greater than both those on A. and B. Similarly, an examination of the three years' wood measurements of trees of Emile d'Heyst, Dr. Jules Guyot and Durondeau shows the same general tendency, whilst in the case of Pitmaston Duchess, Doyenne du Comice and the older series of Durondeau, the figures even at the end of five years are significantly in favour of the trees on C., as can be seen from reference to Table VI.

TABLE IX.

Fertility Pear on Various Quince Stocks six years old. (Units twenty trees.)

Quince Varieties.	Total Wood Growth in metres. 4 years (to 1926).		Girths in mm. 1927.		1928.
		S.E.		*S.E.*	
A.	21.8	*(0.8)*	105	*(2.0)*	145
B.	21.1	*(0.7)*	103	*(1.4)*	140
C.	24.0	*(0.8)*	109	*(1.9)*	144
D.	19.4	*(1.7)*	101	*(4.8)*	137

Even Beurre Hardy shows no exception to the rule of the greater early vigour of trees on C than on A, though with this particular variety, and with Pitmaston Duchess, Quince B. is outstanding for vigour.

All available evidence has been brought to emphasise this fact because of its immediate bearing upon two horticultural maxims.

First, it is often urged that it should be possible from the vigour of any particular rootstock to predict the vigour of the scion worked thereon. Indeed in 1920 it was pointed out that "this very dwarf type" of stock was unfortunately "mixed in with the vigorous type A," and that we were "afraid that this type would be altogether too dwarfing for many varieties of Pear, but this supposition has still to be proved."(1) In fact, we have found here an instance similar to that of the Holstein Doucin No. 4. Apple root stock, which, although it is itself very dwarf in growth, produces vigorous trees.(3)

Secondly, the question of the opposing functions of growth and fruiting are frequently being discussed, and here again, as the records of early blossom production and fruiting, which are about to be presented, will show, the analogy between the behaviour of Pear trees on Quince C, and of Apples on Holstein Doucin (No. 4) can be carried further. The specimen Quince C growing on its own roots at the Station has never reached 6 feet in height and it has never carried a single fruit or blossom, whilst the adjacent specimens of E, F and G have all borne fruits and are double the height.

Blossom Production and Fruiting of Trees on Quinces A, B and C.

In the case of both Conference trials the first appreciable crop was in the sixth year (i.e. 1925 for the first trial and 1927 for the second). In each trial, the trees on Type C. were the only ones to bear any quantity of fruit, in the sixth year, each tree averaging five fruits. Again in both trials the first considerable crop was borne in the seventh year and a comparison of the two is given in Table X. and Figs. 3 and 4.

Table X.

Fruits of Conference Pear in Seventh year on various Quince Stocks. Units of sixteen trees.

On Quince.	1st Series planted 1920–1.		2nd Series planted 1922–3.	
	Average No. per tree.	Rate per acre up to 7th year. lbs.	Average No. per tree.	Rate per acre up to 7th year. lbs.
A. ..	2·5	547	4·5	491
B. ..	3·5	415	3·9	377
C. ..	15·5	2,397	24·1	2,510
D. ..	1·0	—	9·1	—

Fig. 3.
Conference Pear—7 years—on Quince A.

Fig. 4.
Conference on Quince C, same age; compare fruiting and growth habit with Fig. 3.

Fig. 5.
Pitmaston Duchess 7th year— on Quince A.

Fig. 6.
Pitmaston Duchess 7th year—on Quince C; note typical effect of rootstock C on blossoming.

Up to the end of 1928, the cropping of the first series may be presented as follows :

TABLE XI.

On Quince.	Total Number of Fruits. S.E.	Weight in ozs.	Approx. Crop per acre in lbs.
A.	38 (*12.1*)	150	2,831
B.	23 (*4.0*)	101	1,906
C.	62 (*4.8*)	292	5,512

The trees on Type C. are still well ahead in cropping, and, though those on Type A. have apparently cropped much better than those on B, the former have been extremely variable in their performance.

The series of Durondeau and Dr. Jules Guyot trees confirm the early cropping record of Quince C. These trees are now eight years old and the record is as follows :

TABLE XII.

	On Quince A.		On Quince C.	
	Av. No. of fruits per tree.	Weight in ozs.	Av. No. of fruits per tree.	Weight in ozs.
Durondeau	8	32	52	226
Dr. Jules Guyot ..	8	41	15	90

The Fertility trees have borne their first crop in their sixth year (1928) and Table XIII. shows the position.

TABLE XIII.

Cropping of Fertility Pears on various Quince. Sixth year, 1928. *Unit twenty trees. Means per tree.*

	No. S.E.	Weight in ozs.	Estimated Crop per acre. lbs.
A. ..	3.2 (*0.7*)	11	208
B. ..	7.9 (*1.6*)	30	566
C. ..	20.1 (*3.3*)	72.5	1,368
D. ..	4.4 (*1.1*)	15	283

Although the other four varieties have as yet borne no appreciable fruit, probably partly owing to the very exposed site, in at least three cases the records of blossom production confirm very strikingly the early fruit bud

formation upon trees worked on C. (Figs. 5 and 6.) The following figures are typical.

TABLE XIV.

No. of Bloom Trusses on Pitmaston Duchess.

On Quince.	Total Bloom Trusses up to 1926 (6th year).		Bloom Trusses counted after pruning in 1927 and 1928.	
	Mean.	*S.E.*	Mean.	*S.E.*
A. ..	4.1	*(0.9)*	121	*(13.3)*
C. ..	27.4	*(8.3)*	429	*(61.1)*

Doyenne du Comice at the same age averages 107 blossom trusses on Quince C as against 14 on Quince A, and Beurre Hardy 6.75 as against .25 per tree.

In the case of Conference it has been possible to correlate the number of fruits set with the number of blossom trusses. There is no doubt that the trees on C are setting a considerably higher proportion. The following records show this well for the 1928 crop on the younger series.

From an average of 21.7 Blossom trusses, Trees on A produced 4.5 fruits.
16.9 ,, ,, ,, B ,, 3.9 ,,
43.6 ,, ,, ,, C ,, 24.1 ,,
26.5 ,, ,, ,, D ,, 9.1 ,,

Records on the earlier series fully confirm these observations.

Thus these early evidences of the precocity of trees on Type C to blossom and fruit have appeared during a period in which there are lacking any very sufficient figures to prove, or ocular demonstration to show a falling off in vigour. It may be that in the few instances already quoted where the trees on A are apparently now gaining slightly upon those on C, the reason is to be assigned in part to the earlier initiation of the fruiting period in the latter. An examination of records from year to year, however, does not afford sufficient evidence to state this with confidence. The most suggestive case is that of the series of Fertility trees which bore their first crops in 1928. Presumably the year 1927 was one of fruit bud formation, and the increment in girth measurements during that year should give some indication of the effects of this process on the vigour of the trees. As will be seen in Table IX., up to the end of 1926, C had made significantly more wood growth than A, and although the girth measurements on the two stocks were not significantly different, the mean was actually greater for C. For the first time, in spring, 1928, the average girth of trees on C. barely equalled that of those on A, the actual girth increment on the latter having been 40 mm., whereas that on the former was 35 mm. It should perhaps be

emphasised that there must of necessity elapse a considerable period of years before Quince C is in commercial circulation in any quantity.

As usual, Mr. J. Amos has been intimately associated with the writer in the conduct of the experiment throughout ; Mr. A. W. Witt has been responsible for the nursery experiments, and the whole assistant recording staff have made possible the presentation of the data as a result of patient and exact observations. To them and to Miss A. D. MacKenzie has fallen most of the assembling of the figures, whilst Mr. T. N. Hoblyn has given considerable time to examining the data statistically. To all the writer's best thanks are due for making it possible to present in the present form the result of this combined piece of investigation.

SUMMARY.

1. Four varieties of Quince used as root stocks commercially and three others of superior vigour were budded with eight Pear varieties.
2. Whilst the percentage of buds which "took" and the nature of the subsequent "maidens" broadly demonstrated a safe and unsafe group of stocks, peculiar varietal preferences were apparent.
3. The subsequent behaviour of the trees demonstrated various manifestations of "incompatibility" on certain rootstocks, such as the commercial Type D.
4. Though the normal trees on Quinces A, B and C, at present show no significant differences in vigour, those on C have proved outstandingly productive—capacity to make growth and form bloom buds early being united in this variety, which on its own roots is both dwarf and sterile.
5. The vigorous and more free cropping forms of Quince, E, F and G, when used as rootstocks have failed to transmit these characteristics markedly to the scion, even where they have not proved wholly "incompatible."

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(2) *Hatton, R. G., Amos, J.* and *Witt, A. W.* Plum Rootstocks ; their Varieties, Propagation, and influence upon cultivated Varieties, worked thereon. Journal of Pomology & Hort. Science, Vol. VII., p. 69. July, 1928.

(3) *Hatton, R. G.* The Influence of different Rootstocks upon the vigour and productivity of the variety budded or grafted thereon. Journal of Pomology & Hort. Science, Vol. VI., p. 9. 1927.

BOOK REVIEWS.

THE JOURNAL OF THE SOUTH-EASTERN AGRICULTURAL COLLEGE, WYE, 1928. No. 25.

Edited by the REV. S. G. BRADE-BIRKS. 8s. 6d.

The current issue of the Wye College Journal is on the same plan as last year, containing reports of the work of the various departments and a number of papers dealing with original investigations. The variety of subjects discussed is almost bewildering, ranging from pig husbandry and agricultural economics to the details of insect morphology and the chemistry of spray fluids. Many of the articles deal with researches of direct interest to students of horticultural science, and these claim special attention in a notice in this Journal.

Mr. R. T. Pearl has an interesting paper on " Transplanting Fruit Trees " in which he considers the underlying principles and their application in the light of recent work, and includes a valuable list of references. The conclusions reached may be quoted from the author's summary : " The re-establishment of the root-shoot equilibrium is attained after planting, in the absence of pruning, by root growth at the expense of shoot growth, particularly at the start. Root pruning of the coarse roots aggravates this tendency, but branch pruning reverses the effect by temporarily invigorating shoot growth at the expense of the root, and thus bringing about earlier root-shoot balance. Pruning in the season of planting is therefore endorsed, and delaying the pruning for a year tends to check wood growth, and may be serious with old trees, dwarfing stocks, late planting, sandy and heavy clay soils, poor consolidation of the soil. ' De-feathering ' tends to reduce vigour and size of the tree, but blossom removal increases vigour and is desirable at least the first season to prevent the restriction resulting from fruit setting."

Entomological subjects include accounts of the Nut Bud Tortrix moth (*Epiblema penkleriana* Schiff.), and of the Rosy Rustic Moth (*Hydroecia micacea* Fab.) as a hop pest, by Professor Theobald, and a note on the Cherry Fruit Moth (*Argyresthia nitidella* Fab.), by Miss Wimshurst. Mr. H. C. F. Newton contributes two papers on his investigations of the biology and methods of control of flea-beetles of the genus *Phyllotreta* which attack cultivated Cruciferæ. Observations on the life-histories of eight different species are recorded, and special attention is drawn to the liability of an early attack on the seedling plants just before they show above ground. The use of nicotine sulphate either as a spray fluid or dust is recommended and promising results in small scale experiments were also obtained with sodium fluosilicate. Mr. Newton's work was not completed when he left Wye, and in view of the continued serious

annual losses from attacks by flea beetles, it is to be hoped that these investigations will be followed up.

Experiments with pyrethrum as an insecticide are the subject of an article by Mr. M. Austin and Prof. Theobald. A spray fluid prepared by maceration of the ground flowers in soap solution proved very effective against a number of different species of aphides, and against larvæ of Ermine moths ; it was quite ineffective against larvæ of the Gooseberry Sawfly, Magpie Moth, Winter Moth, and Large Cabbage White Butterfly. It is important to note that these results were obtained with an *aqueous* extract of pyrethrum. The substances which give pyrethrum its toxic properties to insects are practically insoluble in water, and the fact that an aqueous extract is effective at all is probably due to emulsification of the resins or other compounds present. The authors refer, at the end of their paper, to the efficiency of an alcoholic extract against Red Spider, and it may be pointed out that by the use of alcohol or other organic solvents, extracts can be prepared which are very toxic to Gooseberry Sawfly larvæ and to many kinds of lepidopterous larvæ. Pyrethrum is, however, undoubtedly specific in its action, and some species are much more resistant to it than others.

To give only the titles of the many other interesting papers in this issue would take up more space than is available, but mention must be made of " A Clay-Farming Episode," by Mr. J. Wyllie and Mr. M. A. Knox. This is a vivid account from the economic point of view, of the experiences of a farmer on the Sussex Weald Clay during the three years 1923-1926, and is of great interest and educational value.

The Journal is an impressive record of the continued activities of the College staff.

C.T.G.

STATISTICAL METHODS FOR RESEARCH WORKERS.*

By R. A. Fisher, Sc.D.

Second Edition.

The fact that this volume has now reached its second edition shows without doubt that it has been of value to workers in all branches of biological research. The present volume is considerably enlarged, the most important addition being a chapter on statistical estimation which will be of considerable value to genetical workers.

It is not intended to review the book in detail here, but rather to indicate briefly one or two ways in which it may help the horticultural research worker.

* Published by Messrs. Oliver & Boyd, 33, Paternoster Row, E.C. 1928. Price 15s.

Nearly all horticultural research deals with small samples, and it is perhaps as yet not generally realised that in such cases greater care must be taken in dealing with the results. Chapter V., in which the significance of means is discussed, particular attention is paid to the means of small samples, and accurate methods for detecting the significance of a difference between two means are presented.

As regards the correlation coefficient (Chapter VI.) a method is discussed whereby it is possible to judge, with increased precision, the significance of an observed correlation between two attributes.

The Chapter on the analysis of variance and the planning of field trials should be studied by all those who have to plan such trials, and particular attention paid to the need for obtaining a truly random sample in order to ensure validity of results.

The examples dealt with are agricultural and it is only recently that attempts have been made to apply these methods of plot arrangement to horticultural field trials. Although the expediencies of horticultural practice may necessitate slight modification, the main principles can be easily applied, and only a little ingenuity and organisation are necessary to carry out experiments arranged on these lines.

The time when hundred per cent. differences (as in the case of varietal cropping differences) in horticultural material were to be looked for, while perhaps not altogether at an end, is fast becoming historical, and in the future smaller, though none the less important, differences will have to be sought. Finer differences need a finer technique to deal with them adequately.

The horticultural worker, then, will do well to read this book, which, while in parts may seem complicated or too technical to the lay mind, is well worth his attention.

T.N.H.

NOTICE.

INTERNATIONAL HORTICULTURAL CONGRESS, 1930.

The International Committee which is responsible for arranging the venues of International Congresses has accepted the invitation given by the Royal Horticultural Society of England to hold the next Congress in London. The Royal Horticultural Society of England is arranging for the Congress to be held in London from Friday, August 8th, to Friday, August 15th, 1930. Papers on horticultural subjects will be read and excursions made to the Horticultural Research Stations.

Further information on the Congress will be published from time to time.

INVESTIGATIONS ON THE FUNGICIDAL ACTION OF SULPHUR.

III*. STUDIES ON THE TOXICITY OF SULPHURETTED HYDROGEN AND ON THE INTERACTION OF SULPHUR WITH FUNGI.

By R. W. MARSH.

Long Ashton Research Station.

Introductory.

In the second paper of this series, the fact was established that when under appropriate conditions sulphur is dusted on to actively growing leaves of certain plants a reaction takes place of which the first identifiable product is gaseous H_2S. In the same paper, Professor Barker referred to investigations on the toxicity to fungi of H_2S which had been carried on at the Long Ashton Research Station and to the forthcoming publication of results. These results are here presented in detail.

The present writer has studied two of the mycological aspects of the problem brought to his notice by Professor Barker. First, the toxicity to fungi of known concentrations of H_2S in air and, secondly, the toxicity of the gaseous products as given off from the sulphured leaves. Further, as the fungicidal property of sulphur is often manifested apart from living green plants, the results are given of certain experiments on the direct interaction of fungi with sulphur. Experiments concerned with the toxicity of H_2S are included in Series A and B; the experiments in Series C deal with the gaseous products from sulphured leaves, while those relating to the interaction of sulphur and fungi are considered in Series D.

The Toxicity of H_2S.

The first recorded observations on this point appear to be those of Pollacci (1875). He found that by passing H_2S into a jar enclosing mildewed grapes, he was able to kill the mildew. The amount and the concentration of the gas were not stated. Foreman (1910), sowed spores of *Botrytis cinerea* in a

* The two previous papers which have appeared in this series are :—

Barker, B. T. P., Gimingham, C. T. and Wiltshire, S.P. "Sulphur as a Fungicide." Long Ashton Ann. Rept. 1919, pp. 57-85.

Barker, B. T. P. "Investigations on the Fungicidal Action of Sulphur: Progress Report." Long Ashton Ann. Rept., 1927, pp. 72-80.

saturated solution (0.25 per cent.) of H_2S kept in a watch glass and found that no inhibition of germination took place.

More exact determinations were made by Wiltshire (1919), who states "With *Sclerotinia fructigena*, the highest concentration in which germination was observed to take place was .002 per cent., but in some cases a solution of .0006 per cent. strength did not give successful germination. In these very dilute solutions, however, there was a great tendency for sulphur to be deposited, and the strength of the solution to be correspondingly reduced."

In view therefore of the scanty information available on the subject further experiments on H_2S were carried out as described below.

As mentioned by Wiltshire, the method of determining toxicity by sowing spores in dilute aqueous solutions of a gas is not satisfactory when dealing with H_2S. In the experiments to be described spores in hanging drops have been exposed to definite concentrations of H_2S in air. This technique is still open to the objection that the toxic substance which actually comes into contact with the spores is possibly a decomposition product of the actual gas. However, the method has such obvious merits for giving comparable results that it has been retained, although it is not claimed that the results refer otherwise than to spores suspended in water. The difficulty of collecting and measuring gaseous H_2S was met by confining it over pure glycerine, in which it is almost insoluble.

SERIES A.

Tests Using Large Volumes of H_2S Mixtures at Fixed Concentrations.

In this series of experiments a stoppered bell jar was used, within which was supported a coverslip bearing spores of the fungus to be tested sown in a drop of nutrient fluid (very dilute malt extract). To the air in the bell jar was added a measured amount of H_2S or of H_2S diluted to 1/10th with air. The bell jar was then kept completely sealed for the duration of the test.

A second bell jar similarly arranged but containing air was used as a control.

Experiment 1.

The concentration of H_2S used in this experiment was 1 in 40,000. This strength was obtained by admitting 1 cc. of a 1 in 10 H_2S-air mixture to a 4-litre bell jar. On the coverslip within the jar were two drops, one containing spores of *Botrytis cinerea*; the other, spores of *Monilia fructigena*, both being obtained from young cultures on sterilised potato. The experiment was carried out three times with the following results:—

TABLE I.

Date.	Duration of Test.	Temperature.	Percentage germination.			
			Botrytis cinerea.		*Monilia fructigena.*	
			Test.	Control.	Test.	Control.
1927. 23 March	11.45 a.m.-5.45 p.m.	17°C.	5	79	13	80
25 March	11.30 a.m.-6.0 p.m.	16°C.	11	40	5	80
29 March	11.15 a.m.-8.15 p.m.	15-16°C.	42	80	1	30

At least 100 spores were counted to obtain each of the figures for percentage germination. In the experiment of March 29th, after the counts, the drop which had been exposed to H_2S was placed in the air chamber and left overnight. By the following morning no more spores had germinated.

The results of other tests made in the same manner showed that H_2S completely inhibits the germination of *Botrytis cinerea* spores at a concentration of 1 in 8,000 and that of *Monilia fructigena* spores at a concentration of 1 in 3,000. Strengths intermediate between these and 1 in 40,000 have not yet been tested against spores of these species. In 1 in 4,000 H_2S no germination of *Fusicladium dendriticum* or *Cladosporium herbarum* spores took place, and 1 in 8,000 prevents germination of spores of *Pencillium verdicatum* and *Physalospora miyabeana*. *Monilia cinerea* spores give no germination in 1 in 40,000 H_2S.

It was thought that possibly the susceptibilities of different fungi to sulphur might be directly correlated with their susceptibilities to H_2S, but no such direct relation was found, In tests of the type described H_2S acts as a general poison, toxic at a low concentration to all the fungi used for experiment. If the toxicity of sulphur is due to H_2S one cannot then assume that the H_2S is formed from the sulphur merely by the action of air, warmth and moisture since, if this were so, sulphur would be equally toxic to any two fungi kept under the same conditions. Some specific reaction of the fungus appears to be involved: this point is further dealt with below (see under Series D).

Experiment 2.

The attempt was made to discover whether a concentration of H_2S sufficient to inhibit germination of *Monilia fructigena* spores, would be tolerated by a flowering plant. For these experiments large glass-fronted metal containers of 78 litres capacity were used, treated on the inside with paraffin wax and provided with a lid that could be sealed on with a vaseline-paraffin luting

mixture. In each container two healthy strawberry plants in pots were placed, together with a slide bearing the spores in a drop of very dilute malt extract. After adding the H_2S to the test chamber the containers were sealed. Relatively high initial concentrations of H_2S were used, no attempt being made to stop absorption of the gas by the soil and flowerpots. Each experiment was carried out overnight. Controls were used in which no H_2S was added. The results obtained are given in Table II. (below).

TABLE II.

Date.	Initial concentration of H_2S.	Average length of Germ-tube produced by 50 spores.		Effect on Strawberry Plants.
		Test.	Control.	
1927.				
5-6 April	1 in 4,000	98μ	197μ	none
6-7 April	1 in 2,000	0μ	320μ	none
11-12 April	1 in 2,000	48μ	248μ	none

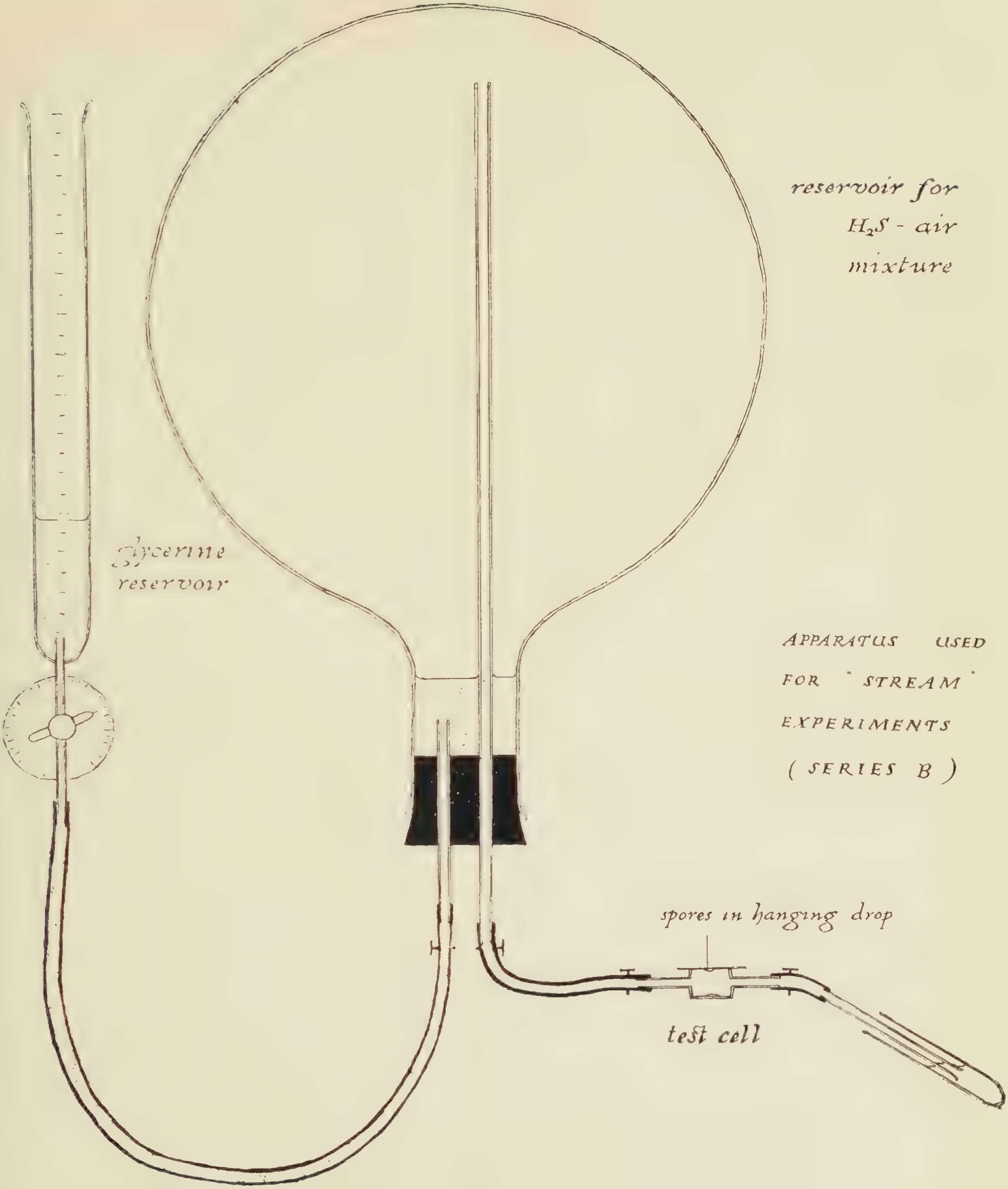
At the conclusion of the experiment of April 6th-7th spores from the test chamber were transferred to fresh drops of malt extract and kept in air to determine their viability. After twenty-four hours at laboratory temperature only 30 per cent. of the spores had germinated and the rate of growth of the germ tubes produced was slower than normal.

These results suggest that by using the correct concentration of H_2S a discrimination of toxic effect may be possible as between flowering plant and fungus. Further experiments of this type are in progress.

SERIES B.

Tests Using a Continuous Stream of Diluted H_2S against Spores in a Ward Cell.

For comparison with the results obtained in experiments with leaves (see below under Series C), trials were made using small cylindrical glass cells (19 mm. diameter and 10mm. deep) provided with inlet and outlet tubes. These cells were closed at the base and ground at the top edge to take a coverslip bearing spores in a hanging drop. The desired H_2S-air mixture was contained over glycerine in a large inverted flask connected to the inlet tube of the cell. By allowing more glycerine to flow into this flask from a burette the H_2S mixture was driven through the test cell. Adjustment of the burette tap gave a means of regulating the flow of glycerine and, consequently, that of the gas. Control



APPARATUS USED
FOR "STREAM"
EXPERIMENTS
(SERIES B)

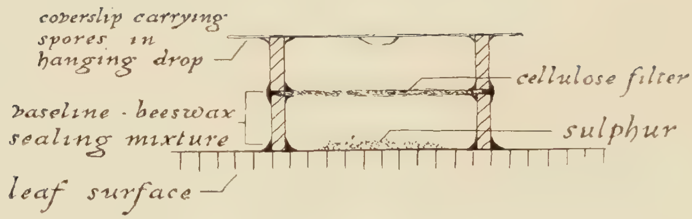


DIAGRAM OF
"FILTER CELL"

experiments were carried out with an entirely similar apparatus in which air was driven through the cell instead of an H_2S-air mixture.

For the most part, the tests were made against spores of *Monilia cinerea*. The results are summarised in Table III. in which reference is made also to tests carried out using spores of *Monilia fructigena* and *Botrytis cinerea*.

Table III.

Spores used.	Date.	Proportion of H_2S in H_2S-air mixture.	Ccs. of mixture passed through test cell.	Duration of experiment (hours).	Total weight of H_2S passed (milligrams).	Milligrams H_2S per hour.	Germination of Spores. Test.	Germination of Spores. Control.
	1927.						%	%
Monilia cinerea	31 Jan.	$\frac{1}{1000}$	112	17	0.100	0.0060	0.7	97
,, ,,	7 Feb.	$\frac{1}{3000}$	109	6	0.054	0.0095	0	95
,, ,,	17 Feb.	$\frac{1}{3000}$	67	7	0.033	0.0047	0	71
,, ,,	14 Feb.	$\frac{1}{3000}$	80	18	0.040	0.0022	31	67
,, ,,	3 Feb.	$\frac{1}{3000}$	55	18	0.027	0.0015	97	99
Monilia fructigena	1 Mar.	$\frac{1}{3000}$	94	10	0.045	0.0045	0	42
Botrytis cinerea	11 Mar.	$\frac{1}{1000}$	44	$5\frac{1}{2}$	0.068	0.0120	0	94
,, ,,	15 Mar.	$\frac{1}{3000}$	96	$6\frac{1}{2}$	0.045	0.0070	0	97

The spores of *Monilia cinerea* which gave no germination in the experiment of February 7th were, after counting, taken off the test cell and kept in a cell containing air for a further twenty-four hours. At the end of this period, 19 per cent. of the spores had germinated ; the remainder were shrunken and apparently dead. The spores of *Monilia fructigena* were similarly tested after the experiment of March 1st and gave no germination. Those of *Botrytis cinerea* after the experiment of March 11th gave a germination of 10 per cent. It appears therefore that the inhibition of germination is accompanied, to a considerable extent, by actual killing of the spores.

The evidence of these experiments corroborates that obtained from the tests in Series A in demonstrating the high toxic value of H_2S against the spores employed. For example, in the experiment of February 17th, it was seen

that a flow through the cell of 9½ ccs. per hour of air containing 1 part in 3,000 of H_2S was sufficient to inhibit all germination of the spores of *M. cinerea*. The deciding factor in these tests appears to be not the total amount of H_2S passed into the cell but the quantity passed per hour. (Note the experiments of February 17th, 14th and 3rd.)

SERIES C.

Tests Employing Leaves Powdered with Sulphur.

In these experiments spores were maintained in a position for germination where they would be subject to the influence of any gas evolved from a sulphured leaf, while at the same time admission of sulphur to the spores was excluded. Both spores and leaf were therefore necessarily kept under somewhat unnatural conditions and it is not known to what extent the results obtained are related to the action of sulphur in actual practice.

The spores were kept in hanging drops on the underside of coverslips which were sealed with vaseline to the top of small rings (11 mm. diameter and 7 mm. deep). Halfway down these rings was a cellulose cross partition to prevent the entry of particles of sulphur into the drop. The rings were placed on the lower epidermis of inverted leaves which were first powdered with sulphur or, in the controls, left untreated. For sealing the lower edge of the ring to the leaf surface a mixture of vaseline and beeswax was melted together, used while still fluid and then allowed to set. The sulphur used was a specially purified sample of flowers of sulphur in the finest state of division obtainable. The spores employed were always taken from young vigorous cultures growing on potato cylinders.

A number of tests were made in which the spores and rings were set up precisely as described above, but glass slides powdered with sulphur were substituted for living leaves. It was thought that the presence of the filter or the products of a possible interaction of sulphur with the sealing materials might exert a depressing influence on the germination of the spores. No such influence could be demonstrated (see, for example, Table VIII.) neither was there any darkening of lead acetate paper when this was kept in the hanging drop instead of the spores.

Experiment 4.

In this experiment, made on July 12th, 1926, twelve rings were sealed to the underside of four young vigorous strawberry leaves on a plant growing in the open. The coverslips over nine of the rings carried spores of *Monilia cinerea* in hanging drops, the remaining three were set up with fragments of lead acetate paper. The cellulose filter was omitted in some of the control rings.

The experiment continued from 9 p.m. to 10 a.m., during which time the temperature fluctuated between 13° and 25°C. The results are shown in Table IV.

Table IV.

		Germination.		
		%	%	%
Spores over untreated leaf surface.	Rings without filter	(Cell 1) 90	(Cell 2) 90	(Cell 3) 80
	Rings with filter	(Cell 4) 90	(Cell 5) 90	(Cell 6) 60
Spores over sulphured leaf surface.	Rings with filter	(Cell 7) 1	(Cell 8) 3	(Cell 9) 10
Lead acetate paper over sulphured leaf surface.	Rings without filter	(Cell 10) No effect.	(Cell 11) Very pale grey.	(Cell 12) Very pale grey.

Rings numbered 1, 4 and 7 were all on the same leaf, 2, 5, 8 and 10 on another and 3, 6, 9 and 12 on a third.

Experiment 5.

In this experiment spores of *Monilia fructigena* were similarly sealed in hanging drops over strawberry leaves powdered with sulphur. Eight rings were used, all having filters, and these were sealed to the undersides of two vigorous strawberry leaves growing in the open. Under four of the rings the leaf surface was sulphured; the remainder served as controls. Rings 1 to 4 were on one leaf, 2 and 3 being on the same leaflet; rings 5 to 8 were on the other leaf, 7 and 8 being on the same leaflet.

The experiment was carried out from 6 p.m. to 10 a.m. on September 12th-13th, 1927, at a relatively low temperature (between 4° and 14° C.). In recording the results, one hundred spores were taken at random in each drop and the germ tubes (if any) from these spores were measured and averaged. (See Table V.)

Table V.

	Average germ-tube production.			
Spores over untreated leaf surface.	(Cell 3) 20μ	(Cell 4) 20μ	(Cell 5) 28μ	(Cell 7) 45μ
Spores over sulphured.	(Cell 1) 0μ	(Cell 2) 0μ	(Cell 6) 4.7μ	(Cell 8) 2.4μ

From these results it is evident that by the interaction of the strawberry leaf with sulphur a gas is produced which has a marked toxic effect on spore germination. A similar, although less marked inhibition was produced when spores of *Monilia cinerea* were kept over sulphured leaves of a willow (*Salix*

americana) and when spores of this species were kept over sulphured leaves of Tomato. No inhibition was demonstrated using sulphured leaves of the following: Black Currant and Quarrenden Apple (tested with *Monilia cinerea*), Rose (tested with *Monilia fructigena*), Oat (tested with *Erysiphe graminis*), or Tomato (tested with *Cladosporium fulvum*).

SERIES D.

Tests on the Interaction of Sulphur with Fungi.

In this series, instead of applying sulphur to a leaf surface, it was applied to living fungus spores or mycelium, and tests were made as before for the evolution of a toxic gas.

The only previous observation on this point which has been found occurs in a paper by Selmi (1875). Selmi, working with moulds growing on Wheat and with *Amanita cæsarea*, states that when these fungi were powdered with sulphur, evolution of sulphuretted hydrogen takes place. He ascribed this action to the production by the fungi of nascent hydrogen.

In the first tests of this present series, the sulphur was placed on a flat fungus fructification to which rings could be sealed as in the leaf experiments of Series C. Another method employed was to seal the rings over sulphur powdered on to a mildew covering a leaf surface. Finally, the sulphur was mixed with spores in a drop on a glass slide, and the ring was sealed over the drop.

Experiment 6.

In this experiment eight "filter rings" were sealed to the hymenial surface of fructifications of *Stereum purpureum* growing on a Poplar log. The rings were placed so as to include the growing margin of the fungus which, under four of the rings, was powdered with sulphur. Six rings carried spores of *Monilia cinerea*; the remaining two carried fragments of lead acetate paper. The experiment was set up in a greenhouse from 6 p.m. to 10 a.m. at a temperature of 14°-16° C. In the record of the results (see Table VI.), the figure given represents the average length of germ tube produced by fifty spores in each drop.

Table VI.

Spores over untreated *Stereum* fructification	(Cell 1) 73μ	(Cell 2) 49μ	(Cell 3) 65μ
Spores over sulphured *Stereum* fructification	(Cell 4) 0.5μ	(Cell 5) 11μ	(Cell 6) 1.4μ
Lead acetate paper over untreated fructification	No change.		
Lead acetate paper over sulphured fructification	Pale grey colouration.		

The production of H_2S and the inhibiting effect are thus clearly demonstrated.

Experiment 7.

Using rings as before, spores of *Monilia cinerea* were kept over *Podosphæra leucotricha* growing on the underside of Apple leaves. Under two of the rings the mildew was dusted with sulphur ; three remaining rings served as controls. The covering of mildew on the leaf surface was so dense that it appeared unlikely that the sulphur would be in contact with the leaf tissue. The experiment was carried out in the Long Ashton plantations from 5 p.m. to 10 a.m. The results are given in Table VII.

Table VII.

Monilia cinerea spores over :—	Average germ-tube production (50 spores).		
Podosphæra leucotricha on Apple leaf ..	(Cell 1) 41μ	(Cell 2) 70μ	(Cell 3) 49μ
Sulphured *Podosphæra leucotricha* on Apple leaf	(Cell 4) 27μ	(Cell 5) 13μ	

These results suggest that an interaction takes place between the Apple mildew fungus and the sulphur, this action being accompanied by the evolution of a gas having an inhibiting effect on spore germination. Attempts to demonstrate a similar effect after applying sulphur to *Sphærotheca pannosa* on Rose and *Cladosporium fulvum* on Tomato were not successful.

Experiment 8.

This was set up to determine whether H_2S could be evolved, by direct interaction of sulphur with the spores of *Monilia fructigena* and of *M. cinerea*. In this experiment the spores used were obtained from naturally infected Plums. The arrangement of the tests and controls is given in Table VIII. ; ten cells were used, without filters, each carrying a fragment of lead acetate paper on the coverslip. The experiment ran from 3 p.m. to 10 a.m. at a temperature of 14°-17°.

Table VIII.

Materials at base of cell.	Effect on lead acetate Paper above.
Water and sulphur	No change.
Malt extract and sulphur	No change.
Spores of *Monilia fructigena* and water	No change.
Spores of *Monilia fructigena*, water and sulphur ..	Dark grey colouration.
Spores of *Monilia fructigena* and malt extract ..	No change.
Spores of *Monilia fructigena*, malt extract and sulphur	Dark grey colouration.
Spores of *Monilia cinerea* and water	No change.
Spores of *Monilia cinerea*, water and sulphur ..	Grey colouration.
Spores of *Monilia cinerea* and malt extract	No change.
Spores of *Monilia cinerea*, malt extract and sulphur	Grey colouration,

Experiment 9.

This experiment resembled the foregoing, but differed from Experiment 8 in that the filter cells were employed and spores of *Monilia fructigena* were used on the coverslip in the place of lead acetate paper. The duration of the experiment was from 5 p.m. to 10 a.m., and the temperature 24°. The arrangement of the experiment and the results are given in Table IX.

TABLE IX.

Monilia fructigena spores over :—	Average germ-tube production (40-50 spores).	
Water	(Cell 1) 183μ	(Cell 2) 197μ
Water + sulphur	(Cell 3) 197μ	(Cell 4) 190μ
Water + *M. fructigena* spores	(Cell 5) 169μ	(Cell 6) 211μ
Water + *M. fructigena* spores + sulphur	(Cell 7) 0μ	(Cell 8) 79μ

Experiment 10.

In Experiment 9, the spores used at the base of the cells were taken direct from Plums, so it was thought advisable to carry out a further test in which all the spores used were taken from pure cultures. Another slight alteration was made in the arrangement of the experiment, as it had been found that the sulphur in the drop at the base of the test cells tended to dry up the liquid. In the present series the control cells were set up with French chalk at the base, so that this drying effect should be approximately equal in all the cells. The experiment was carried out from 3 p.m. to 10 a.m. at 27° C.; the results are given in Table X.

TABLE X.

Monilia fructigena spores over :	Average germ-tube production.		
M. fructigena spore suspension and French chalk	(Cell 1) 197μ	(Cell 2) 103μ	(Cell 3) 176μ
M. fructigena spore suspension and sulphur	(Cell 4) 2μ	(Cell 5) 0μ	(Cell 6) 0μ

When the cells 4, 5 and 6 were opened, they smelt distinctly of H_2S. A further test made with lead acetate paper showed that a marked sulphide reaction was obtained, as in Experiment 7.

The production of H_2S by direct interaction of sulphur with spores in this manner suggests an explanation for the effect of sulphur when added, for example. to a spore suspension of *M. fructigena*. The inhibition of germination which then takes place is, in general, greatest when the spores are actually in contact with the

sulphur, but it is also marked throughout the drop, and any germ-tubes produced, even although they do not come into contact with particles of sulphur, remain much shorter than normal. It would then appear that the inhibition of growth of such germ tubes must be due to a compound formed from the sulphur and capable of diffusing through the liquid. The experiments described above suggest that this compound is H_2S.

Experiment 11.

The writer has already suggested that the toxicity of sulphur to a given fungus depends upon the interaction of the organism with the sulphur. For further investigation of this point, spores from pure cultures of *Monilia fructigena* and of *Botrytis cinerea* were taken and set up in filter cells in various combinations, with and without sulphur. The experiments were carried out at 27° C. and care was taken that the atmosphere of the cell remained saturated with water vapour.

With moist sulphur alone at the base of the cell, and spores of either fungus above, no inhibition of germination took place. Neither was there any inhibition if *Monilia* spores were grown over *Monilia*, *Botrytis* over *Botrytis*, *Monilia* over *Botrytis*, or *Botrytis* over *Monilia*. If *Botrytis* spores mixed with sulphur were placed at the bottom of the cell, the spores germinated and formed a vigorous mycelium with conidiophores, and no inhibition resulted if spores of *Monilia* or of *Botrytis* were kept at the top of the same cell. But if *Monilia* spores were mixed with sulphur, evolution of H_2S took place, and spores of either genus kept in the same cell germinated very slightly or not at all. Results of a typical experimen are given in Table XI.

Table XI.

Botrytis cinerea spores over :—	Average germ-tube production.		
Botrytis cinerea and sulphur	(Cell 1) 170μ	(Cell 2) 200μ	(Cell 3) 190μ
Monilia fructigena and sulphur	(Cell 4) 0.2μ	(Cell 5) 45μ	(Cell 6) 0μ

It might be objected that too much has been assumed from results obtained solely from tests made in small enclosed cells. A further experiment was therefore made under conditions of greater aeration.

Experiment 12.

Two drops of a spore suspension of *Monilia fructigena* were placed uncovered on a slide which was kept in an inverted bell jar of four litres capacity. Water was present in the bottom of the jar to ensure saturation of the atmosphere. Flowers of sulphur were added to one of the drops and French chalk to the control

drop. The bell-jar was then sealed and kept at 12°-13° for nineteen hours. At the end of this period the average length of germ tube produced in the control drops was 325μ: that in the drop containing sulphur was 35μ. It is thus seen that the inhibiting effect of sulphur remains well marked even in a drop exposed to a large volume of air.

Discussion.

It is generally recognised that the addition of powdered sulphur to a drop containing spores of *Monilia fructigena* is sufficient to inhibit the germination of these spores. It is now demonstrated by experiments 8-11 (above) that from such an admixture of sulphur and *M. fructigena* spores, sulphuretted hydrogen is produced. *Botrytis cinerea*, on the other hand, is not checked by addition of elemental sulphur, although growth of the spores of *Botrytis cinerea* is inhibited by H_2S (see Experiments 1 and 11).

The simplest hypothesis which would meet these facts is the assumption that sulphur is toxic only by virtue of the H_2S produced from it: that the production of H_2S from sulphur can be brought about by certain living organisms, and that a fungus "sensitive to sulphur" is one which can act upon the sulphur to produce H_2S. The germinating spore of such a fungus, on coming into contact with a sulphur particle, exercises a self-poisoning effect, analogous with that produced by fungus spores acting on the precipitate from Bordeaux mixture.

When sulphur is placed on a flowering plant which also bears fungus spores or mycelium the possibility of two methods of action must be considered. Either the fungus or the green plant may be active towards the sulphur, that is, may react with the sulphur to form H_2S, as suggested above. Again, both plant and fungus may be inactive, or one may be active and the other not. With a plant growing in the open, it seems probable that any H_2S formed might be carried away before it could be effective, but, in a greenhouse, the H_2S produced by the plant might be a factor of importance. Thus, the growth of a fungus such as *Botrytis cinerea*, inactive towards sulphur, might be inhibited if on a sulphured plant capable of giving rise to H_2S, while the same fungus on another host might not be affected by sulphur.

As the reactions of the green plant with sulphur remain under examination, a discussion of the meaning of the expression "active towards sulphur" cannot usefully be included at this stage. It is hoped, however, that with the elucidation of the mechanism of the leaf-sulphur reaction, some light will also be thrown on the method of interaction of sulphur with fungi.

I have pleasure in expressing my gratitude to the Director of the Long Ashton Research Station, Professor Barker, to whom I am indebted for the suggestion of this line of work and for help and advice throughout its progress.

SUMMARY.

1. The high toxicity of H_2S to germinating spores of several species of fungi has been demonstrated by quantitative experiments made *in vitro*.

2. The possibility of a discrimination of this toxic effect as between flowering plant and fungus has been shown.

3. Spores kept under the influence of the gases evolved from the sulphured leaves of strawberry and other plants have shown marked inhibition of germination.

4. Results are given which indicate that the "sensitiveness" of certain spores to sulphur is an indication of the ability of such spores, on germination, to interact with sulphur with the production of H_2S.

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INVESTIGATIONS ON CHLOROSIS OF FRUIT TREES.

IV. THE CONTROL OF LIME-INDUCED CHLOROSIS IN THE FIELD.

By T. WALLACE, M.C., M.Sc., A.I.C.

In papers I. and II. (19, 20) of the present series, results of chemical investigations on fruit trees in cases of lime-induced chlorosis were reported.

It was shown in those papers that the trees in question were all growing on soils containing high amounts of calcium carbonate, and that the foliage and stem portions of the terminal shoots of the chlorotic specimens, in all cases, showed definite and similar characteristics in the composition of the ash, etc., when compared with material from shoots bearing green leaves. Reference was also made to the fact that the particular chlorosis studied at these centres was associated with deficiency of iron, since the chlorotic foliage could be changed to a normal green by painting or spraying solutions of ferrous sulphate at appropriate strengths on the affected leaves.

Since the problem is of economic importance in certain of the large fruit areas in the country, experiments with a view to devising suitable methods of controlling the malady on a commercial scale were initiated at the centres previously reported on simultaneously with the chemical investigations.

This phase of the work has been in progress over four seasons and results have been obtained which it seems desirable to place on record at the present time.

The experiments have been confined, with one exception, to determining the value of sprays and of cover crops as means of effecting commercial control. The results reported show that while spraying methods do not appear to be suitable, cover crops seem to provide a suitable and cheap means of effecting a large measure of control over the condition.

HISTORICAL.

As early as 1845, it was shown by Gris (5) that chlorosis in plants growing on calcareous soils in France was associated with iron deficiency, and that the condition could be remedied by treating the affected plants with iron salts. Since that time, numerous investigators have studied the problem in various parts of the world and in all cases, with comparatively rare exceptions, have found that the condition was associated with iron deficiency and was amenable to appropriate treatment with iron salts. Since extensive bibliographies of this work have been given by previous writers such as Leroux (10), reference will be

made here to only a few of the contributions which deal with special points considered in this communication.

One of the most notable cases in which a lime-induced chlorosis has not been associated with iron deficiency is that which has been investigated at the Rhode Island Experiment Station, U.S.A. (2, 3), where it has been shown that the chlorosis is characterised by a deficiency in manganese and has been remedied by means of managanese compounds applied either to the foliage as sprays or to the soil incorporated in fertilisers.

In cases of lime-induced chlorosis associated with iron deficiency, the main problems relating to the control of the trouble have been to find methods of introducing the requisite amounts of iron into the affected plants without injuring them, and in effecting improvements of sufficient duration to render the methods of practical value. Among the chief methods tested have been the following*: application of iron salts to the soil; spraying the foliage with solutions of iron salts at appropriate strengths; painting cut surfaces of branches with iron solutions; injecting solutions and crystals of salts into holes bored into branches as far as the wood.

In such experiments, it has been usual to find that ferrous sulphate is the most efficient compound to use. Applications direct to the soil have not generally been successful, though it is stated that chlorosis of Pineapples in Hawaii can be controlled by the *frequent* application of small doses of ferrous sulphate in this way (17), whilst Hendrickson (6) reports successes on Pear trees as old as fifteen years from applying crystals of this salt near the roots of the trees by means of trenches and by holes bored in the soil with a soil auger, and watering the crystals applied to dissolve them. Trees treated in this way with 15 to 20 lbs. of ferrous sulphate per tree remained green for two years and showed only slight chlorosis in the third season.

Considerable success has been obtained on some plants by spraying methods (8, 9), and, according to Johnson (8), iron salts are applied to the leaves of Pineapples commercially on considerably over one half of the Hawaiian Pineapple fields. It is to be noted, however, that all investigators agree that good effects from sprays are always temporary, and the operation needs either fairly, or very, frequent repetition. It has also been the general experience that the effects of the sprays are confined to the areas actually covered by them, and do not spread appreciably; and often, because of this, the green colour developed takes the form of spotting.

Results from injections and dipping have also been found to be of a temporary character, and although these methods are regarded favourably by some workers (11), they are pronounced uncertain and unsafe by others (6), owing to the liability of injuring the plant by their use.

* Dusting with Marcasite has been recently suggested (17).

Three further methods by which lime-induced chlorosis associated with iron deficiency has been controlled or mitigated require mention, all being described by Gile and Carrero (4).

The first is by the application of very large doses of stable manure to the soil in cases of chlorosis of sugar cane and Pineapples ; the second by incorporating in the soil large amounts of bulky organic materials such as Tobacco stems, Velvet Beans, etc., where Rice was the test plant ; and the third, again using the Rice plant, by submerging the soil under water to a depth of three inches.

None of these three methods is suitable for application to fruit trees, as the first two, even if successful in controlling the chlorosis, would induce rank, undesirable growth, and produce fruits of inferior quality, whilst the third treatment would speedily lead to the death of the tree.

Whilst it has been demonstrated repeatedly that plants suffering from lime-induced chlorosis react to appropriate treatment with iron salts, the manner in which the plants develop " iron deficiency " is not understood. Opinions differ even on the point as to whether the iron content of chlorotic plants is less than that of comparable green plants, and it is not definitely established whether plants become chlorotic primarily because they are unable to absorb sufficient iron from the soil or whether the deficiency arises within the plant as the result of the iron becoming immobile from some internal cause (13).

It is difficult to ascertain from chemical analysis of green and chlorotic plants which of these views is correct and, whilst from experiments on the application of ferrous sulphate to the soil, it appears true that plants do not obtain iron readily from chlorotic soils (6) it has been amply demonstrated in spraying, painting and injection experiments that iron salts are relatively immobile within chlorotic plants.

The manner in which calcium carbonate induces chlorosis has been studied by several workers but its action is not understood. In this connection, however, it has been shown that iron becomes less available to plants with increasing alkalinity of the nutrient medium (12) and that the form in which the iron is present in the soil (ferrous or ferric) may be of great importance (1).

EXPERIMENTAL.

As stated previously, the experiments described in this paper relate, with one exception (an injection experiment), to the use of sprays and cover crops as means of effecting a commercial control of lime-induced chlorosis of fruit trees. The experiments have usually been carried out on apple trees, though, in one case, Plum trees were used and, in another, observations were made on Pear trees.

The specific objectives of the spraying experiments were as follows :

1. To determine the best strength of ferrous sulphate solution to use to effect control without causing spray damage, and to ascertain the duration of the beneficial effects of such sprays.
2. To determine whether control could be effected with aluminium sulphate solution, used at an appropriate strength.

The experiments with aluminium sulphate were included to see whether a sufficiently acid reaction could be imparted to the chlorotic tissues to render abnormally immobile iron within the plant more mobile.

The experiments with cover crops were initiated for two reasons. In the first place it was observed that on certain chlorotic areas, trees growing under grass conditions seemed much less susceptible to chlorosis than did others growing under arable conditions.

Secondly, good results on chlorotic plants had been obtained by Gile and Carrero (4) by incorporating heavy dressings of stable manure and various bulky organic residues into soils. The idea was conceived that the beneficial effect might be produced by the increased content of carbon dioxide in the soil atmosphere resulting from such treatment lowering the pH value of the soil. If this were true, then a similar result might be expected by growing crops such as grass, clover, lucerne, etc., over the root systems of affected trees, since it appears from the investigations of several workers (14, 16, 18) that similar concentrations of carbon dioxide in the soil air result from growing such cover crops and from incorporating in the soil dressings of stable manure.

In connection with the possible effect of the carbon dioxide content of the soil air in lowering the pH value of the soil solution, it should be stated that whilst it has been demonstrated that by passing carbon dioxide into suspensions of soils giving alkaline reactions the pH values may be substantially lowered, it has not been established definitely that the increased concentration of CO_2 of the soil air, due to growing crops, effects any reduction in the pH value of the soil (7, 15).

The experimental difficulties of examining the point critically are great, and investigators who have failed to establish this latter effect of CO_2 in their experiments are not prepared to rule out the possibility of its occurring *in situ*, since it seems feasible that such effects may be produced very locally in proximity to absorbing root hairs (15).*

It has been stated that one injection experiment was carried out. It is not proposed to present this in detail, but it will suffice to record that the introduction of a small quantity of ferrous sulphate crystals into a branch bearing chlorotic foliage effected a temporary improvement similar to that described by various workers.

* See also. Truog. E. "How Plants Feed." Proc.: First Internat: Congress of Soil Science. Commiss: 3 & 4, P630.

*Experiments with Sprays.**

Spraying experiments were carried out at six centres during the seasons 1924 and 1925, and observations on the results of the treatments have been made at one of the centres over the period 9th June, 1924, to 4th July, 1927, in order to observe the duration of the initial effects produced.

The data from the experiments are assembled in Table I. The soils at the centres used, with the exception of Centre F, have all been described in Paper I. of this series, and by referring to the Geological Formations shown in the above table and those given in Table I., Paper I., it is possible to identify the centres. The soil at Centre F is a calcareous boulder clay, overlying a heavy calcareous Lias clay. The percentages of calcium carbonate in the surface and subsoil are as follows: surface soil, 7.02 per cent.; subsoil, 9 in. to 18 in., 12.66 per cent.; subsoil, 18 in. to 30 in., 16.94 per cent.

Preliminary trials were carried out with ferrous sulphate at Centre A in 1924 to obtain information on the strength of spray solutions in relation to efficiency and damage. It was found that a 1.0 per cent. solution was more effective than one of 0.5 per cent. strength, and the observation was made that the addition of a suitable spreader was necessary to wet the foliage adequately.

The main trials were carried out in 1925, and in these ferrous sulphate and aluminium sulphate were tested, in all cases a spreader (an organic base caseinate) being added at 0.1 per cent. strength. By the aid of this spreader very thorough wetting of the foliage was obtained in all cases.

The salient points shown by the data in Table I. are as follows:

Ferrous Sulphate.

1. Ferrous sulphate used at 1 per cent. strength was in some cases very effective in controlling the chlorotic condition during the season of application, e.g., Centre C, variety Monarch; in others the control effects were variable, e.g., Centre C, variety Newton; and in others good effects were practically negligible, e.g., Centre F.
2. 1.0 per cent. strength was more effective than 0.5 per cent. or 0.25 per cent. Results with 0.25 per cent. at Centre D. were negligible.
3. Where the duration of effects was observed at Centre A, it was noted that these were only temporary. In the second and third seasons after spraying, all beneficial effects had usually disappeared completely.
4. Damage to the foliage from 1.0 per cent. solution was sometimes very serious, especially where the chlorosis was in an advanced stage. Note damage at Centre F.

* Experiments described at Centres A, B, C, are in conjunction with Mr. A. D. Turner. Mr. C. E. T. Mann was also associated with these experiments during 1925.
The records of Centre D. for September 21st, 1925, were taken by Mr. N. Bagenal.

TABLE I.

Spraying Trials.

Centre	Geological Formation	Particulars of Trees.	Particulars of Sprays, etc.	Observations on Chlorosis.	Damage from Sprays.
A.	Dolomitic Conglomerate	Apple—var.: Duke of Devonshire; age 11 years in 1924.	9/6/24. Some branches sprayed with $FeSO_4$ at 0.5% and 1.0% strength. 12/6/25. Whole tree sprayed with 1.0% $FeSO_4$ + organic casein spreader.	9/6/24. Sprayed branches, Chlorosis bad. 23/9/24. Sprayed foliage showed some improvement. 1.0% $FeSO_4$ more effective than 0.5%. 12/6/25. Chlorosis bad. Very little residual effect from previous spraying. 4/9/25. Chlorosis slight to medium. One branch bad. Spray effective some branches. 4/7/27. Chlorosis bad. Previous effects of sprays not retained.	Severe, usually as burning in spots.
		Apple—var.: King of the Pippins; age as above.	9/6/24. Do. 12/6/25. Do.	9/6/24. Chlorosis bad. 23/9/24. Some improvement. 12/6/25. Chlorosis bad. 4/9/25. Chlorosis medium to bad. Slight improvement from spraying. 4/7/27. Chlorosis bad.	Severe, as marginal scorching.
		Apple—var.: Rich's Favourite; age as above.	12/6/25. Whole tree sprayed with 1.0% $FeSO_4$ + organic casein spreader.	12/6/25. Chlorosis very bad. 4/9/25. Chlorosis slight to medium, some branches; others practically no effect from spray. 4/7/27. Chlorosis very bad.	Slight except on most chlorotic branches where severe.
		Apple—var.: Wellington; age as above	Do.	12/6/25. Chlorosis very bad. 4/9/25. Chlorosis very slight. Only a few leaves chlorotic. Spray very effective. 4/7/27. Chlorosis medium. One branch bad. Some improvement still maintained.	Slight.
		Apple—var.: Peasgood Nonsuch; age as above.	12/6/25. Whole tree sprayed with 1.0% $Al_2(SO_4)_3$ + organic casein spreader.	12/6/25. Chlorosis bad. 4/9/25. Chlorosis bad. No visible effect from spray.	Very slight.

TABLE I.—*continued.*

Centre	Geological Formation	Particulars of Trees.	Particulars of Sprays, etc.	Observations on Chlorosis.	Damage from Sprays.
B.	Inferior Oolite.	Apple—var. : King's Acre Pippin ; age 3 years.	12/6/25. Sprayed with 1.0% $FeSO_4$ + organic casein spreader.	12/6/25. Chlorosis bad. 4/9/25. Chlorosis medium. Most chlorotic foliage much green spotting. Definite improvement.	Slight.
		Do.	12/6/25. Do.	12/6/25. Chlorosis very bad. 4/9/25. Chlorosis bad. Chlorotic leaves show green patches and spots. Slight improvement.	Slight.
		Apple—Four trees, var. : Lane's Prince Albert ; age 3 years.	12/6/25. Do.	12/6/25. Chlorosis bad all trees. 4/9/25. Chlorosis only very slight all trees.	Slight spotting.
		Apple—Five trees—var. : Lane's Prince Albert ; age 3 years.	No spray. Controls to Lane's above.	12/6/25. Chlorosis bad all trees. 4/9/25. Chlorosis slight all trees. Show much natural recovery. Definitely more chlorotic than $FeSO_4$ sprayed trees.	
		Do.	12/6/25. Sprayed with 1.0% $Al_2(SO_4)_3$ + organic casein spreader.	12/6/25. Chlorosis bad all trees. 4/9/25. Chlorosis medium. More severe than controls. No visible improvement from spray.	Negligible.
C.	Lower Lias.	Apple—var. : Monarch ; standards in nursery ; age 3 years. Ten trees.	12/6/25. Sprayed with 1.0% $FeSO_4$+ organic casein spreader.	12/6/25. Chlorosis bad. 4/9/25. Chlorosis practically nil all trees. Spray very effective.	Negligible.
		Do.	No spray. Control for above.	12/6/25. Chlorosis variable. Mostly bad. On whole slightly better than sprayed trees. 4/9/25. 6 trees Chlorosis bad. ; 2 trees Chlorosis medium ; 2 trees Chlorosis slight.	
		Apple—var. : Newton Wonder ; standards in nursery. Ten trees.	12/6/25. Sprayed with 1.0% $FeSO_4$+ organic casein spreader.	12/6/25. Chlorosis bad. 4/9/25. 1 tree Chlorosis bad ; 2 trees Chlorosis medium ; 1 tree Chlorosis slight to medium ; 4 trees Chlorosis slight ; 2 trees Chlorosis slight.	

TABLE I.—*continued.*

Centre	Geological Formation	Particulars of Trees.	Particulars of Sprays, etc	Observations on Chlorosis.	Damage from Sprays.
D.	Chalk.	Apple—var.: Worcester, Cox's Orange Pippin.	12/6/25. Preliminary trials with $FeSO_4$ at 1.0%, 0.5%, 0.25% strengths to ascertain damage.	12/6/25. Chlorosis bad. Trees in very poor condition.	?/6/25. 1%, trees practically defoliated. 0.5%, serious defoliation. 0.25%, no defoliation.
		Apple—3 trees—var.: Cox's Orange Pippin; age 7 years.	?/6/25. 0.25% $FeSO_4$ + organic casein spreader.	12/6/25. Chlorosis bad all trees. 21/9/25. Chlorosis bad. No visible effect.	
		Do.	?/6/25. 0.25% $Al_2(SO_4)_3$ + organic casein spreader.	12/6/25. Chlorosis bad all trees. 21/7/25. Chlorosis bad. No effect.	
		Apple—3 trees—var.: Worcester Pearmain; age 7 years.	3/6/25. 0.25% $FeSO_4$ + organic casein spreader.	12/6/25. Chlorosis bad all trees. 21/9/25. Chlorosis bad. No effect.	
		Do.	?/6/25. 0.25% $Al_2(SO_4)_3$	12/6/25. Chlorosis bad all trees. 21/9/25. Chlorosis bad. No effect.	
E.	Keuper Marl.	Apple—3 trees—var.: Lord Grosvenor; age 10 years.	?/6/25 1.0% $FeSO_4$ + organic casein spreader.	?/6/25. Chlorosis bad all trees. 21/9/25. Chlorosis medium to slight. Spray had produced visible effects.	Slight.
		Apple—3 trees—var.: Lord Grosvenor; age 10 years.	?/6/25. 1.0% $FeSO_4$+ organic casein spreader.	?/6/25. Chlorosis bad all trees. 21/9/25. Chlorosis bad. Spray no effect.	Negligible.
F.	Drift over Lower Lias.	Plum—var.: Purple Pershore; age 16 years.	17/5/25. 1.0% $FeSO_4$+ organic casein spreader.	17/5/25. Chlorosis bad. 11/5/27. Chlorosis bad.	25/5/25. Foliage and young fruits severe burning effects. Leaves crippled.

Aluminium Sulphate.

6. This material did not produce beneficial effects in any cases.
7. Damage from its use was less than from ferrous sulphate used at equal strength.

Experiments with Cover Crops.

Experiments on the use of permanent cover crops have been carried out at three Centres, viz. D. E. F.

Those at D. and E. have been on a fairly large scale and have extended over several seasons—D. 1925 to 1928 inclusive, E. 1924 to 1928 inclusive, whilst at F. only a small number of trees have been used and the observations have extended over two seasons only.

At Centre D. it has also been possible to make a general observation for one season on the effect of a cover crop on approximately seven acres.

Centre D.—(In conjunction with N. Bagenal.)

The trees used in this experiment were bush Apple trees of the varieties Cox's Orange Pippin and Worcester Pearmain. They had been planted about seven years when first seen in June, 1925.* Up to that time they had been growing under conditions of clean cultivation and had gradually developed very severe chlorosis. In 1925, previous to the experiment, practically every tree was markedly chlorotic, there being only occasional trees which were retaining any considerable proportion of green foliage.

For the purposes of the experiment on cover crop effects, a portion of the field was divided into plots which were located side by side and separated from each other by buffer rows.

The details of the trees in each plot, together with the cover crop treatments which have been given, are shown below. The plots are listed in the order of occurrence in the field.

Plot I. Tumbledown grass, run with ducks from August, 1925.

Cox's Orange Pippin: 20 trees in 3 rows.
Worcester Pearmain: 10 trees in 1 row.
Total trees, 30.

Buffer Row a. As Plot I, one side and as Plot II the other.

Cox's Orange Pippin: 21 trees in 1 row.
Total trees, 21.

Plot II. Clean cultivation until August, 1926; since then tumbledown grass + wild white clover.

Cox's Orange Pippin: 27 trees in 1 row.
Worcester Pearmain: 33 trees in 1 row.
Total trees, 60.

* The trees in Plot V. were one year younger.

Buffer Row b. As Plot II. one side and as Plot III. the other.
Cox's Orange Pippin: 38 trees in 1 row.
Total trees, 38.

Plot III. Lucerne from July, 1925. Crop cut and left on ground.
Cox's Orange Pippin: 148 trees in 3 rows.

Buffer Row c. As Plot III. one side and as Plot IV. the other.
Worcester Pearmain: 56 trees in 1 row.
Total trees, 56.

Plot IV. Tumbledown grass and wild white clover from August, 1925.
Cox's Orange Pippin: 451 trees in 8 rows.
Worcester Pearmain: 114 trees in 2 rows.
Total trees, 565.

Buffer Row d. As Plot IV. one side, clean cultivation the other.
Cox's Orange Pippin: 51 trees in 1 row.
Total trees, 51.

Plot V. Clean cultivated until August, 1926; since then tumble down grass and wild white clover.
Cox's Orange Pippin: 108 trees in 2 rows.
Worcester Pearmain: 55 trees in 1 row.
Total trees, 163.

The following notes, taken on the dates of recording the intensity of chlorosis in the seasons 1926, 1927, 1928, show the condition of the cover crops in those seasons and refer to certain points of management of these which affected the occurrence of chlorosis.

July, 1926.

Plot I. was under tumbledown grass and was stocked with ducks. The grass had made a fairly good cover and consisted chiefly of *Poa annua*. There were a few bare patches, chiefly around the duck house.

Buffer a. Cover was as for Plot I. on one side and as for Plot II. on the other.

Plot II. The soil was cultivated and practically free from weeds.

Buffer b. One side was as for Plot II. and the other as for Plot III.

Plot III. The lucerne had made a fairly good cover. It had been cut once and the hay left to rot.

Buffer c. One side was as for Plot III. and the other as for Plot IV.

Plot IV. The cover of grass and clover was rather thin, the growth of the clover being patchy.

Buffer d. One side was as for Plot IV. and the other as for Plot V.

Plot V. The area was cultivated and practically free from weeds.

August 5th, 1927.

The area from Plot I. to Buffer *d*. was all stocked with ducks at the rate of 160 birds per acre. Houses to accommodate them had been erected on the plots. Small areas, usually a few square yards, around the houses, were generally worn bare by the ducks and on all such areas a few trees showed marked chlorosis.

Plot I. The cover was very poor, many areas having been worn bare by the ducks. Chlorosis on the plot occurred on these areas.

Plot II. The cover was fairly thin, the clover being only poorly developed.

Plot III. The lucerne had made very strong growth and had provided an excellent cover.

Plot IV. There was a good cover of clover.

Plot V. The cover was fairly thin and the clover not well developed.

The herbage of the Buffers on this date showed the characters of the plots on either side of them.

July 25th, 1928.

The cover was good over the whole area of the plots, with the exception of some worn patches on Plot I. and of small areas around the duck houses.

On this occasion, it was evident that wherever the cover afforded by any of the cover crops was thick, chlorosis (apart from capsid damaged trees—see below) was negligible.

The method of marking the intensity of chlorosis on each occasion was as follows :

Nil : Tree free from chlorosis.

Trace : A small proportion of the foliage slightly chlorotic.

Slight : A fair proportion of chlorotic foliage. The chlorotic condition easily observable but not serious.

Medium : The foliage was generally more or less chlorotic but there was a certain proportion of green leaves and shoot growth was not visibly affected.

Bad : Chlorosis severe, shoot growth restricted and in some cases branches dying back.

Where the condition of a tree was judged to be intermediate between two categories, a plus or minus sign was added to the marking recorded to show whether the condition tended to be less or more severe than the category marked.

For the purpose of presenting the results in this paper, numerical values have been assigned as follows :

Trace	$\frac{1}{2}$
Slight	1
Slight to Medium	$1\frac{1}{2}$
Medium	2
Medium to Bad	$2\frac{1}{2}$
Bad	3

Capsid damage was very severe on the trees in 1927 and 1928, and especially so on Cox's Orange Pippin. This rendered recording very difficult in those seasons, since the pest-affected trees developed late terminal growths of a semi-chlorotic character and it appeared on recording that many trees marked as chlorotic—generally in the category " trace "—would have been marked as nil but for such effects. In 1928, a large number of trees bearing this type of foliage were marked " trace ? " and have been calculated as $\frac{1}{4}$.

The markings in these seasons are thus doubtless on the high side. Terminals injured by scab and mildew also produced late growths of this type.

The results calculated by the above method have been summarised in Table II. for the seasons 1926-1928.

TABLE II.

Showing Markings for Chlorosis per Tree.

Plot No.	No. of Trees. recorded.	1926.	1927.	1928.
Plot I.	30	0.60	**1.35**	0.33
Buffer a.	21	*1.52*	0.66	0.31
Plot II.	60	**1.64**	0.23	0.11
Buffer b.	38	*1.64*	0.82	0.14
Plot III.	148	0.52	0.65	0.12
Buffer c.	56	0.31	0.72	0.10
Plot IV.	565	0.74	0.75	0.17
Buffer d.	51	*1.07*	0.65	0.12
Plot V.	163	**1.75**	0.55	0.10

There is one point which requires mention in connection with the method of presentation of the data. This is that the values for the two varieties have not been presented separately in the Table. The reasons for this are as follows :

It is not intended that the values should be regarded as being strictly quantitative. The severity of the chlorosis on the two varieties prior to cover crop treatments was very similar, and on the large majority of trees would have been classed as "Medium" (numerical value 2). The final results for the varieties were also very similar, as can be seen by comparing the results for the Buffer Rows b, c and d, d being comprised entirely of Worcester and b and c entirely of Cox's Orange Pippin. The only significant differences between the varieties which were observed occurred in 1927, when two rows of Worcester—Buffer Row c and a row in Plot IV.—showed more severe chlorosis than any row of Cox's Orange Pippin. The difference, however, was easily accounted for, since it was noted that the chlorotic foliage of the Worcester trees in question was borne on secondary growths of terminals and was thus of abnormal occurrence.

The salient features to be noted in the data are as follows:

In 1926, after one season of treatment, the intensity of the chlorosis on all the cover crop plots was markedly less than that on the cultivated Plots II. and V. and on the Buffer Rows a, b and d receiving cultivation on one side of the tree rows.

The grassing down treatments given to Plots II. and V. from the August of 1926 reduced the severity of the chlorosis on those plots and on the adjoining buffer rows previously under half cultivation during 1927.

The effects of intensive stocking with ducks in 1927 on Plot I., which led to the partial destruction of the cover crop, is shown in the increased figure recorded for chlorosis on that plot.

In 1928, on all plots with the exception of Plot I. and Buffer Row a, the amount of chlorosis was practically negligible. The slightly higher values on those two plots were noted as due to incomplete covering of the surface by the cover crop.

The figures show conclusively the effect of the various cover crops in controlling the chlorotic condition on the plots.

It should be added that even in 1927, when the values on the area from Buffer Row a to Plot V. are shown as usually greater than 0.5, reaching a value of 0.82 on Buffer Row b, an attempt was made to obtain a sample of terminal shoots bearing wholly chlorotic leaves for analytical purposes, but it was found impossible to do so.

After noting the good effects following the establishment of the cover crops on the experimental area, the whole of the area of the plantation outside the plots was left uncultivated during 1927 and white clover sown over it. Previous to this, chlorosis was general over this area and in August, 1928, after two seasons of this tumbledown grass plus clover treatment, the only trees on the area remaining chlorotic were a few Pear trees, which appear to be highly susceptible to the trouble.

CENTRE E.*

The trees at this centre are bush Apple trees, the varieties being Lane's Prince Albert, Lord Derby, Rev. Wilks and Red Victoria with a few odd trees of the variety Crimson Bramley. The block had been planted for five seasons when first inspected by the writer in 1924. At that time, chlorosis was distributed more or less generally over the whole area though there were patches where the trouble was extremely severe and others where it was relatively slight. As the result of differences due to variation in intensity of chlorosis, some of the less affected trees of the variety Lane's Prince Albert measured 6 feet in height, whilst the most severely affected were less than 3 feet high and had made no progesss since planting.

The whole of the area subsequently used as the experimental area was allowed to tumble down to grass and weeds from July, 1924. The trees were not marked individually previous to this, only a general note being made on the trees, since in the first place it was proposed to observe only very large effects, such as the difference between the possibility or impossibility of growing trees on the area under the two cultural conditions, as it was recognised that under cultivation, the trees were rapidly declining and, in many cases, would soon be quite useless.

During 1925, the area was covered with a growth of grass consisting almost entirely of *Poa annua*. The effect of this treatment was remarkable. Many of the trees which had previously been very severely chlorotic and in a stagnant condition produced terminal shoots from 1 foot to 2 feet in length and bore normally green foliage.

The individual trees of a single row containing sixteen trees, running through the worst area, were recorded, using the method described for the experiment at Centre D, and it was found that the average marking was less than a trace, the highest value being slight +.

Since then the plot has been used to study three points : the permanency of the grass effect, the rate of development of the chlorotic condition following the resumption of cultivation, and the management of the "grassed" trees to prevent nitrogen starvation.

Cultivation was resumed in August, 1925, on the row recorded in that year, and from August, 1926, four more rows adjoining it were put under cultivation. Two further rows were added to the cultivated section from winter 1927-28.

During 1926, a portion of the grassed area was dressed with sulphate of ammonia at 2 cwts. per acre and in 1927 and 1928 only a portion of this area received sulphate of ammonia, at the rate of 3 cwts. per acre, a larger area being

* Mr. C. Taborn has applied the sulphate of ammonia at this centre and assisted with the recording in the seasons 1926, 1927 and 1928.

Mr. F. E. T. Mann was responsible for the 1926 records.

left in these years with the treatment "grass only." In the autumn of 1927 the trees on the plots were thinned, alternate trees being removed.

The method of recording the degree of chlorosis was the same as described at Centre D., and the records have been assigned numerical values in the same way. Here again the records have not been analysed separately for the different varieties, since the differences between varieties have been very small in comparison with the differences due to cultivation and grass treatments, and the various plots have contained the different varieties in approximately equal proportions.

TABLE III.

Showing Chlorosis Marking—as Averages per Tree.

Season	Cultural Treatment, etc.	No. of Trees. recorded.	Chlorosis marking as average per tree.
1925	1 year under grass.	16	0.33
1926	1 year cultivated after 1 year grass.	16	1.00
	2 years grass.	64	0.06
	2 years grass + sulphate of ammonia at 2 cwts. per acre second year.	128	0.14
1927	2 years cultivated after 1 year grass.	16	1.00
	1 year cultivated after 2 years grass.	64	0.23
	2 years grass, then 1 year half cultivation, half grass (buffer row).	16	0.17
	3 years grass (48 received sulphate of ammonia 1926)	96	0.03
	3 years grass + sulphate of ammonia 1926, 1927.	48	0.19
1928	3 years cultivated after 1 year grass.	8	1.31
	2 years cultivated after 2 years grass	32	0.60
	1 year cultivated after 1 year half cultivated, following 2 years grass.	8	0.22
	1 year cultivated after 3 years grass.	14	0.07
	4 years grass (received sulphate of amonnia 1926)	32	0.07
	4 years grass + sulphate of ammonia 1926, 1927, 1928.	24	0.01

The growth of the cover crop at this centre has not been very vigorous, since it has been composed throughout the experiment chiefly of *Poa annua* and has tended to " burn " badly during late July and August. The growth of the plot receiving sulphate of ammonia during all three seasons was stronger than on the remainder of the grassed area.

The results are presented in Table III. in an appropriate form to show the important points which have emerged.

The most striking point of the data is, of course, the very large difference between the values for the cultivated and grassed areas and it is obvious that at this centre the cover crop has again exercised a considerable measure of control over the chlorosis.

The second feature of interest is the rate of return of chlorosis following the resumption of cultivation after varying periods of grass treatment, this point being clearly shown in the data for 1928.

CENTRE F.

The trees observed at this centre are Plum Trees of the variety Purple Pershore, stated to be sixteen or seventeen years of age in 1926.

Chlorosis had been developing gradually for a few seasons previous to the above year and growth, which had been good in the early stages, had gradually fallen off.

In August, 1926, all the trees concerned, about twelve in all, were markedly chlorotic. An attempt to control the chlorosis on a few branches with 1.0 per cent. sulphate of iron in May, 1925, resulted in serious foliage damage and the trees again showed severe chlorosis during that season.

The area was sown down to rye grass in the Spring of 1928 and an excellent cover was obtained during that season.

The condition of the trees was observed on July 20th and on that occasion the amount of chlorosis present was negligible.

DISCUSSION.

The results described in the experiments with sprays show that the method does not appear to be a suitable one for controlling chlorosis of Apple and Plum trees on a commercial scale.

Beneficial effects from ferrous sulphate, which is generally recognised as the most efficient material for the purpose, are uncertain, and considerable damage to the foliage occurs from its use in many cases.

The experiments with cover crops show that this method is likely to prove of great value in controlling cases of lime-induced chlorosis in this country. The experiment at Centre D. can be regarded as having been carried out under

extreme conditions of soil, since the latter is derived from pure chalk rock, the surface soil containing 60.0 per cent. of calcium carbonate and the subsoil consisting of chalk rubble.

The method as one for use on fruit trees such as the Apple and Pear has the advantage over all methods previously described in that it is simple, involves no extra trouble or expense, requires no special skill to carry out, and does not affect the fruit quality adversely.

The only point which requires mention regarding its use is that trees grown under such conditions soon become starved due to lack of nitrogen, and it will be necessary in many cases to apply fairly heavy dressings of quick-acting nitrogenous manures such as nitrate of soda or sulphate of ammonia at rates possibly as heavy as 5 cwts. per acre each year. On theoretical grounds sulphate of ammonia will probably be more suitable than nitrate of soda for this purpose.

The reasons for testing the cover crop method have been stated previously but the mechanism of the action has not been investigated. It should be mentioned, however, that it has been shown in a previous paper (19) that chlorotic leaves rendered green by the use of either ferrous sulphate or cover crops show the same change in relationship in the ratio of $\frac{Ca}{K}$ in passing from the chlorotic to the green condition, which suggests that the cover crop, when effective, influences the functioning of iron within the tree, either by increasing the intake of iron or by rendering active some portion of the iron already contained in the tissues.

CONCLUSIONS.

1. The action of ferrous sulphate sprays in controlling lime-induced chlorosis of fruit trees associated with iron deficiency, is uncertain ; such sprays sometimes produce good results and in other cases the beneficial effects are very small. Considerable damage may result from their use.

2. Aluminium sulphate used as a spray does not exercise any controlling effect over lime-induced chlorosis of fruit trees.

3. Considerable control of lime-induced chlorosis of fruit trees may be obtained by growing permanent cover crops over the root systems of the affected trees. The method appears to be of considerable commercial value.

SUMMARY.

1. A brief account is given of the utility and limitations of methods previously used for controlling lime-induced chlorosis in various plants.

2. Reference is made to the views of investigators on the causes of lime-induced chlorosis and the possible mechanisms of the various ameliorative measures proposed.

3. Experiments on the use of sprays containing ferrous sulphate and aluminium sulphate and the effects of cover crops as means of controlling lime-induced chlorosis of fruit trees associated with iron deficiency are described. It is shown that while spraying methods are unsuited for commercial purposes on fruit trees, the use of cover crops appears to offer a simple and effective means of controlling the trouble.

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THE OCCURRENCE OF CHLORATES IN A TOMATO SOIL.

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Early in the 1927 season a tomato grower in this district reported a case of severe injury to tomato plants. The plants affected were confined to two houses, and in these particular houses the effects appeared to be confined to certain areas, in which the plants made practically no growth. Soon after planting, the lower leaves became desiccated and eventually dropped off, while the tips of the plants showed a peculiar mottle bearing a slight resemblance to the symptoms of mosaic disease of the tomato described by Bewley (2). Later on the plants which survived, brown lesions appeared on the stems.

The affected areas had been replanted several times without success, and liberal dressings of sulphate of potash were without avail. The only difference in the treatment of these and other houses on the nursery in question was that they were trenched during the 1926–7 winter. In all other respects the treatment of the soil throughout the nursery was the same.

Owing to its economic importance the phenomenon was investigated, with the further hope that the cause of the injury might be connected with the low fertility of " sick " tomato soils. Accordingly a large sample of the soil from the affected houses was examined at this Station.

After potting up young plants in the soil, it was soon evident that the distribution of the toxic principle was very uneven. For instance, on a hot sunny day some of the plants were showing symptoms within two hours. Others potted at the same time did not show any ill-effects for twenty-four hours. This was found to be in agreement with the analytical data obtained later. The potency of the toxic principle was shown when a well-established tomato plant growing in a normal soil rooted through the bottom of the pot and the roots came into contact with quite a small amount of the toxic soil. Within quite a short time on a hot day the plant was showing the typical symptoms. It did not appear likely that the injury was due to a gas or easily volatile compound since a healthy plant in a normal soil showed no untoward effect during enclosure under a bell-jar with some toxic soil for several days.

Early experiments on the effect of some compounds on the soil indicated that ammonium sulphate delayed the appearance of the symptoms, whilst addition of hydrated lime at the soil surface appeared to accelerate it. In all the later experiments which necessitated the potting up of plants, a large batch of the soil was mixed up well to ensure a uniform distribution of the poison for each particular experiment.

THE SOLUBILITY OF THE POISON.

Extraction of the poison from the soil was attempted with water, acetone, alcohol and ether. After removal of the organic solvents from the residual soil, plants potted up in it soon showed the typical symptoms. The rate of development of these symptoms indicated that ether had extracted least, whilst alcohol and acetone were inferior to water in this respect. This was confirmed when the solid matter extracted in each case was applied to plants growing in a normal soil. It may be added that washing with water does not appear to affect the complete removal of the principle from the soil. A sample of soil washed with twenty-five times its own weight of water imparted the symptoms to plants within eighteen days, whilst plants in a corresponding sample of unwashed soil were affected within three days.

THE AQUEOUS EXTRACT.

For stock purposes extracts were prepared by stirring up 1,000 gm. of soil with 1 litre of water. After settling, the supernatant solution was decanted on to a hard filter paper on a Buchner funnel and suction applied. 500 c.c. of water were used to transfer the soil on to the funnel, and finally another 500 c.c. of water were used to wash it on the funnel. The filtrate was eventually concentrated and, without filtering from any solid matter which sometimes separated during evaporation, was made up to 1 litre, so that 1 c.c. of the solution corresponded with 1 gm. of the original soil. Examination of such extracts revealed the following facts :—

(1) 25 c.c. applied to 300 gm. of normal baked soil caused a plant growing in it to show typical symptoms in three days.

(2) 5 c.c. with 20 c.c. of water under the same conditions caused the appearance of symptoms within seventeen days.

(3) 25 c.c. showed no definite reactions with the usual alkaloidal or protein reagents.

(4) Autoclaving for seven hours at 30 lbs. pressure had no effect on the toxicity.

(5) Prolonged boiling with 20 vol. hydrogen peroxide was without effect on the toxicity.

(6) Evaporation and subsequent gentle ignition of the residue caused the toxicity to disappear.

The effect of autoclaving on the extract is curious in that the toxicity persists even after seven hours, whereas autoclaving the soil itself for one-and-a-half hours caused the toxicity to disappear. This was repeated with different batches of soil with the same result, and similar observations were made in Dr. Bewley's laboratory.

The facts quoted suggested that the compound sought for was inorganic, and further work was based on this assumption. A determination of the solids extracted by water in the soil and in a corresponding normal soil from the same nursery yielded the following results:—

	Total solids extracted per cent. on oven dried soil.	Per cent. residue after ignition of solids.
Toxic soil	0.426	0.283
Normal soil	0.224	0.156

The excess of solids in the abnormal soil was in part due to chlorides and sulphates, as the following figures show :—

	Per cent. SO_4 extracted.	Per cent. chloride extracted.
Toxic soil	0.0885	0.0233
Normal soil	0.0277	0.00612

That the toxicity was not due to either the chlorides or sulphates was shown in two ways. Firstly, the careful removal of sulphates and chlorides from a toxic extract was without effect on toxicity, and secondly, the addition of chlorides and sulphates, together and separately, in excess of the concentrations found, produced none of the symptoms.

Concurrently with these experiments, the effect of heat on the soil was being examined. As already stated, autoclaving the soil caused the toxicity to disappear, and the same result followed quite gentle ignition. At the same time the chloride content of the soil fell. This was also the case when an aqueous extract was evaporated and gently ignited. It must be remarked that these evaporations and ignitions were carried out in silica vessels. In a number of determinations the apparent chloride content fell when determined either by direct titration or by Volhard's method. This appeared to rule out the possibility of salts of any of the oxy-halogen acids being present, since they would, of course, cause an increase in the halide content on ignition. It appears that in these particular soils the chlorides are, partly, at all events, volatile or are converted into volatile chlorides.

This fall in the chloride value on heating considerably delayed the solution of the problem, and it was only after a considerable amount of fruitless work that the examination of a chloride-free extract was returned to. It was found that such an extract lost its toxicity on evaporation and gentle ignition and, furthermore, that the residue gave positive tests for a chloride. This pointed to the presence of a chlorate or a perchlorate. That it was not the latter was proved by the fact that the chloride-free extract after reduction with ferrous sulphate showed the presence of a chloride. There remained the remoter possibilities of bromates or iodates, since the silver salts are slightly soluble

in water, and also of hypochlorites. That it could only be a chlorate was amply proved by pot experiments in which baked soil was used and each of the possible compounds added as sodium and potassium salts. The hypochlorites, iodates and bromates at concentrations equivalent to that of the chlorate estimated in the toxic soil produced no effect on young tomato plants. Bromates and bromides at low concentrations appeared to stimulate the plants. Perchlorates, however, did produce a peculiar mottling of the foliage, and eventually some lesions on the stems, but the chlorates alone reproduced the effects observed on plants growing in the toxic soil. Confirmation was also obtained in a concentrated extract corresponding to 100 gm. of the soil. This extract was concentrated to about 20 c.c. and a large excess of 95 per cent. alcohol added. This caused the precipitation of a fairly voluminous amount of solid matter which, after filtration and removal of alcohol, was without effect on a plant growing in normal soil. The alcohol in the extract was removed by distillation and the residue finally dried. Treatment of the residue with concentrated sulphuric acid gave the typical reaction of a chlorate.

Estimation of the Chlorate.

Åslander (1), in a recent paper describes the determination of a chlorate in a soil extract. The chlorate was reduced by standard ferrous sulphate and the excess ferrous sulphate estimated. This method was not applicable in the present instance. When extracts of the toxic soil were mixed with potassium iodide mere traces of acid were sufficient to liberate iodine, suggesting that iodates or bromates were present. Since any iodate or bromate present would react like a chlorate with ferrous sulphate, any method using this reaction must be corrected accordingly. Actually, two methods were tried, one a gravimetric and the other volumetric. In the first a known volume of the soil extract was treated with an excess of 10 per cent. silver nitrate. It was considered that in the presence of such a concentration of silver the silver iodate would be rendered completely insoluble and then removed along with the silver chloride during filtration. The excess of silver was removed by sodium carbonate and the chlorate eventually reduced by ferrous sulphate. Sufficient nitric acid was then added to dissolve the basic iron salt and the chloride precipitated as silver chloride and weighed as such.

In the second method the total chlorides were determined, before and after reduction by ferrous sulphate, by Volhard's method, both determinations being carried out in fairly large amounts of water in the hope that the small amount of silver iodate would remain in solution. The difference in the determinations corresponded to the iodide and chloride produced from the original iodate and chlorate, and were calculated as chlorate (bromates appeared to be absent). In a separate portion of the extract iodates were estimated by treatment with

potassium iodide and 1 per cent. of 33 per cent. acetic acid as recommended for water analysis by Thresh and Beale (4). This iodate content was calculated to the equivalent chlorate and deducted from the value found by titration.

The agreement shown by these two methods was satisfactory in the cases selected, and the second method was used for the later determinations. For instance, the values given in two cases by the gravimetric and volumetric methods respectively were 0.01542 and 0.01526, and 0.01922 and 0.01887 per cent. $NaClO_3$. For different batches of soil the volumetric method gave among others, the following values, 0.0193, 0.0284 and 0.0297 per cent. on oven dried soil. This last figure was the highest recorded during the work, and was given by an extract prepared by washing 300 gm. of soil with 7.5 litres of water.

The iodate content was also variable but, calculated as sodium iodate, generally varied between 15 and 25 per cent. of the sodium chlorate concentration.

The origin of these chlorates has not been traced, and the matter is rendered difficult by the localisation of the compounds in the glasshouses concerned. The iodates no doubt have their origin in Chili saltpetre, which is certain to have been used on the soil, as Scharrer and Schwaibold (3) have shown that practically all the iodine in Chili saltpetre is present as iodate.

An interesting feature of this soil was the gradation of effect on tomato plants when grown in the soil diluted to different degrees with normal baked soil. This effect was reproduced exactly with both potassium and sodium chlorates. A sample of the soil which contained chlorate equivalent to 0.0245 per cent. $NaClO_3$ was diluted with baked soil in the ratios 3:1, 1:1, 1:3, 1:5, and compared with baked soils to which potassium and sodium chlorates had been added in amounts equivalent to those contained in the mixtures of toxic and baked soils.

Within a week of planting, all the plants in each series were showing the typical symptoms. The gradation in effect was definite in each series. On the whole the plants treated with sodium chlorate were slightly more affected than the corresponding plants in the potassium series. This will be seen from the photographs.

In conclusion, it is interesting to note that at the conclusion of the 1927 season the soil in the houses where the plants were affected was steamed, and during the following season tomato plants were grown in the soil without any ill-effects.

Grateful acknowledgments are made to Mr. A. L. Holland for his assistance with the cultural part of the work, and to Mr. E. R. Speyer, M.A., who took the photographs.

FIG. 1.
Tomato Plant growing in normal baked soil.

FIG. 2.
Tomato Plant growing in normal soil to which has been added 0.0245 per cent. $NaClO_3$.

FIG. 3.
Tomato Plant growing in normal soil to which has been added 0.0282 per cent. $KClO_3$.

FIG. 4.
Tomato Plant growing in the toxic soil.

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GENETICAL AND CYTOLOGICAL ASPECTS OF INCOMPATIBILITY AND STERILITY IN CULTIVATED FRUITS.

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In previous reports on these experiments the results have been presented in detail (Sutton, 1918 ; Crane, 1923-5). Since the last report appeared, numerous pollinations have been made, and in the present paper recent and past results are summarised in order to present a concise account of the investigations, and to avoid the publication of an excessive amount of tabular matter. The results obtained during the past four years, hitherto unpublished, are included in the gross summaries. The pollinations have been continued on trees grown in pots, and under the same methods of control described in earlier papers.*

Sterility in fruits is of three fundamentally different kinds, (i) *generational sterility*, due to the failure of any of the processes concerned with the normal alternation of generations ; namely, development of pollen, embryo sac, embryo and endosperm, and the relation of these with one another and with their parents regardless of the cross made ; (ii) *morphological sterility*, due to suppression or abortion of sex organs, and (iii) *incompatibility*. In this third form of sterility we are not dealing with sterility in the strict sense of the word, as both the ovules and the pollen—or at least a good proportion of them—are functional. The failure to obtain fruits from self and cross incompatible pollinations is due to the absence of fertilisation, the pollen tubes becoming arrested in the nutrient stylar tissue. On the other hand in compatible pollinations although the same pollen and ovules take part, the pollen tubes travel the full length of the style. The male and female nuclei fuse, and the fertilised ovary develops into a fruit.

CHERRIES.

We have previously shown that self-incompatibility appears to be general and cross-incompatibility of frequent occurrence in our cultivated varieties of the sweet cherry. Further investigations have substantiated our earlier conclusions, and in Table I. are given the varieties of the sweet cherry used in these experiments and the compatible and incompatible combinations so far elucidated. + = compatible ; — = incompatible combinations.

* A detailed account of the practical aspects of our pollination experiments with fruit trees has appeared in an earlier paper published in this Journal, Crane (Vol. VI.).

♀ \ ♂	BEDFORD PROLIFIC	BLACK EAGLE	BLACK TARTARIAN "A"	BLACK TARTARIAN "B"	EARLY RIVERS	KNIGHT'S EARLY BLACK	ROUNDELL	BIGARREAU DE SCHRECKEN	BIGARREAU FROGMORE	GUIGNE DE WINKLER	WATERLOO	WINDSOR "A"	NAPOLEON	EMPEROR FRANCIS	WHITE BIGARREAU	KENTISH BIGARREAU	LUDWIG'S BIGARREAU	LATE BLACK "B"	BOHEMIAN BLACK "A"	TURKEY HEART "B"	BELLE D'ORLEANS	BELLE DE ST. TRONC	BLACK HEART	BLACK TARTARIAN "E"	EARLY PURPLE GEAN	ELTON	FLORENCE	GUIGNE D'ANNONAY	GOVERNOR WOOD	GEANTE DE HEDELFINGEN	MONSTRUEUSE DE MEZEL	JABOULAY	NOBLE	NOIR DE GUBEN	NOIR DE SCHMIDT	WHITE HEART
BEDFORD PROLIFIC	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+			+	+	+		+		+	+	+	+		+			+	+	+	+	+
BLACK EAGLE	−	−	−	−	−	−	−	+	+	+	+		+	+		+	+	+	+	+										+					+	
BLACK TARTARIAN "A"	−	−	−	−	−	−	−	+	+	+	+		+	+				+		+	+			+					+							
BLACK TARTARIAN "B"	−	−	−	−	−	−	−	+	+	+	+		+	+						+				+		+		+				+		+		
EARLY RIVERS	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+		+	+	+	+		+	+		+				+	+	+	+			+	
KNIGHT'S EARLY BLACK	−	−	−	−	−	−	−	+	+	+	+		+	+	+			+				+		+					+			+			+	
ROUNDELL	−	−			−	−	−			+	+			+				+																		
BIGARREAU DE SCHRECKEN	+	+	+	+	+	+	+	−	−	−	−		+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	
BIGARREAU FROGMORE	+	+	+	+	+	+	+	−	−	−	−	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		+	+			+		+	
GUIGNE DE WINKLER	+	+	+	+	+	+	+	−	−	−	−	+	+	+	+	+	+	+	+	+		+		+	+		+		+	+	+	+		+	+	
WATERLOO		+	+	+	+	+	+	−	−	−	−		+	+	+	+		+									+									
WINDSOR "A"		+							+	+		−	−	−	+					+																
NAPOLEON	+	+	+	+	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+				+	+	+	+	+		+	+		+	+	
EMPEROR FRANCIS	+	+	+	+	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+		+		+	+	+	+		+	+	+	+		+	+	
WHITE BIGARREAU		+							+	+			+		−	−	−		+													+			+	
KENTISH BIGARREAU					+			+	+	+	+		+		−	−	−										+	+				+		+	+	
LUDWIG'S BIGARREAU	+					+					+	+		+	−	−	−	+									+					+				
LATE BLACK "B"	+	+		+	+		+	+	+	+	+			+		+	+	−	−	−		+			+				+					+	+	
BOHEMIAN BLACK "A"	+	+	+		+	+	+	+	+	+	+		+	+			+	−	−	−										+				+		
TURKEY HEART "B"	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−							+			+	+				+	
BELLE D'ORLEANS			+		+								+								−															
BELLE DE ST. TRONC	+								+				+									−										+		+		
BLACK HEART					+			+	+														−			+										
BLACK TARTARIAN "E"	+		+	+	+				+															−					+						+	
EARLY PURPLE GEAN					+			+					+												−											
ELTON					+			+	+				+	+		+				+			+			−		+				+				
FLORENCE	+							+		+			+	+		+	+										−									
GUIGNE D'ANNONAY					+			+						+														−								
GOVERNOR WOOD	+	+	+	+	+	+	+	+	+	+	+		+	+		+				+				+					−	+	+		+	+		
GEANTE DE HEDELFINGEN		+								+			+														+			−			+			
MONSTRUEUSE DE MEZEL		+						+		+			+	+	+	+	+									+					−					
JABOULAY	+			+	+	+	+	+	+		+		+	+	+	+	+	+				+			+		+		+			−		+	+	
NOBLE	+		+		+				+	+			+	+						+									+	+			−			
NOIR DE GUBEN							+	+	+	+												+		+	+							+		−		
NOIR DE SCHMIDT	+	+			+		+	+	+	+	+	+	+	+	+		+	+	+	+					+		+		+		+	+	+	+	−	
WHITE HEART					+			+																												

TABLE I.

CONFUSION OF NOMENCLATURE.

Considerable confusion prevails in the nomenclature of cherries ; different individuals are frequently met with under the same name, and to meet one individual under two or more names is also common. Since Table I. was prepared we have determined that Windsor " A " is the same as Bigarreau Napoleon ; Bohemian Black the same as Turkey Heart ; White Bigarreau the same as Kentish Bigarreau, and we suspect that Belle de St. Tronc and Belle d'Orleans are the same. There is no question of the others not being distinct individuals, but the identity of some remains obscure. It will be noted in Table I that three individuals bear the name Black Tartarian ; they are all distinct and are designated " A ", " B " and " E ".

Guigne de Winkler is incorrectly named and should be Belle Agathe (see Bunyard (1925). Ludwig's Bigarreau in Group IV. is not the true Ludwig's, but it is distributed under that name, and for the present we refer to it as such. It has red fruits whereas those of Kentish Bigarreau, its co-incompatible are mainly cream. Kentish Red and Kentish Red " A " are quite distinct.

The gross totals of (a) self-pollinations, (b) cross-incompatible pollinations and (c) cross-compatible pollinations made between the varieties given in Table I are as follows :—

	No. of flowers pollinated.	No. of fruits set.	Percentage set.
Self-pollinations	29,059	26	0.08%
Cross-incompatible pollinations ..	23,904	28	0.12%
Cross-compatible pollinations ..	53,922	14,216	26.3 %

In this and all subsequent summaries, " number of fruits set " means the number which reached maturity.

There is reason to believe that some of the fruits obtained in the selfing and crossing of incompatible varieties are the result of accident, but on the other hand occasional fruits have set under very stringent conditions, which suggests that as a rarity a pollen tube travels the full length of the style and effects fertilisation. When seedlings raised from these occasional fruits reach maturity the behaviour of pollinations between them and their parents may afford evidence of their origin ; but fruits form so rarely in these incompatible pollinations that they are not of practical significance.

The investigations of others, e.g. Sprenger (1908), Gardner (1913), Schuster (1922-5), Florin (1923), Hooper (1924), Wellington (1926), and Tufts, Hendrickson and Philp (1926) have also shown that it is exceptional to obtain fruit from self-pollinated flowers in the sweet cherry.

The average set of 26 per cent. obtained from the cross-compatible pollinations is the equivalent of a good yield, but among these compatible crosses considerable variation occurs as is shown in Table II.

PLATE I.

P. avium var. LATE BLACK.

Showing examples of (F) self-incompatibility, (E) cross-incompatibility, (A.B.C.) cross-compatibility and (D.) fruit from inter-specific pollinations.

Photograph by H. C. Osterstock.

PLATE II.

Victoria Plum Self-Pollinated.

609 flowers, 196 fruits = 32.1 per cent.

Photograph by H. C. Osterstock.

Table II.

	Flowers.	Fruit.	% set.
Black Tartarian "A"	2369	217	9
White Bigarreau	644	79	12
Black Tartarian "E"	385	53	13
Black Eagle	1329	187	14
Bigarreau Noir de Schmidt	2060	350	16
Kentish Bigarreau	2862	485	16
Early Rivers	2224	386	17
Geante de Hedelfingen	232	41	17
Ludwig's Bigarreau	501	100	19
Early Purple Guigne	358	75	20
Knight's Early Black	638	140	21
Turkey Heart	4604	1015	22
Roundell	150	33	22
Black Tartarian "B"	712	164	23
Monstrueuse de Mezel	630	151	23
Waterloo	517	123	23
Black Heart	409	100	24
Bigarreau de Schrecken	6520	1622	24
Bigarreau Jaboulay	1003	267	26
Emperor Francis	3445	913	26
Belle de St. Tronc	325	93	28
Guigne de Winkler	2493	722	28
Noble	141	40	28
Belle d'Orleans	803	237	29
Late Black Bigarreau	2658	798	30
Bigarreau Frogmore	3559	1140	32
Elton	1349	441	32
Florence	329	109	33
Bigarreau Napoleon	2623	990	37
Bedford Prolific	3310	1261	38
White Heart	225	86	38
Bigarreau Noir de Guben	1685	667	39
Guigne d'Annonay	628	252	40
Governor Wood	1919	831	43

The age of the tree, the kind of crop it carried in the previous year, and whether flowers were borne abundantly or otherwise are frequent causes of such differences. But when due allowances have been made for the influences of these factors, it becomes increasingly clear that they are not the only cause of the variation. Reference to Table II. shows that striking differences occur in the proportion of fruit set in the compatible pollinations among the varieties used in the experiments. Since many individuals have been used to pollinate each of the varieties the results are more likely to be the expression of degrees of generational sterility. This naturally will be more evident on the female side, e.g., whereas 70 per cent. of bad pollen might not detract from the efficiency of a variety as a pollinator, such a proportion of sterility among the ovules would result in a lower yield.

Pending extensive histological investigations it is of course impossible to determine just how much this varietal variation in yield is the result of what may be termed in a broad sense environmental influences, or how much is due to

sterility, but that both are involved is evident. It is possible that in certain cross-pollinations a proportion of the pollen may be incompatible—see Text Fig. 2b—and with respect to differences of yield, such a possibility must not be precluded.

In the Sour and Duke Cherries varying degrees of self-compatibility occur. In Table III. the results obtained from self-pollinating varieties in these groups are detailed.

TABLE III.

Variety.	No. of Flowers pollinated.	No. of Fruits Set.	Percentage.
Morello	5,402	966	17.8
Kentish Red "A"	2,044	426	20.8
Wye Morello	1,790	120	6.7
Flemish Red	762	50	6.5
Kentish Red	2,981	0	0.0
Lake Duke	4,179	408	9.7
Empress Eugenie	700	24	3.4
Archduke	3,059	73	2.3
Royal Duke	1,047	13	1.2
May Duke	4,789	60	1.2
Reine Hortense	4,193	0	0.0

The results obtained from cross-pollinations between Sweet, Sour and Duke cherries have varied considerably. Sweet varieties as females, pollinated by sour varieties as male, generally produce and mature fruits freely, but from reciprocal pollinations, fruits are less freely formed. The Dukes are also less productive when used as females with the Sweet Cherries than when used as males. The total results of such crosses are summarised in Table IV.

TABLE IV.

Variety.	No. of Flowers. pollinated.	No. of Fruits set.	Percentage.
Sweet Cherries × Sweet Cherries ..	53,667	14,168	26.3
Sweet Cherries × Sour Cherries ..	2,953	703	23.7
Sour Cherries × Sweet Cherries ..	1,144	93	8.1
Sweet Cherries × Dukes	4,786	601	12.5
Dukes × Sweet Cherries	2,406	129	5.3
Sour Cherries × Dukes	353	42	11.8
Dukes × Sour Cherries	1,317	45	3.4
Sour Cherries × Sour Cherries ..	489	60	12.2
Dukes × Dukes	534	44	8.2

The extent of the trials of pollinations with Sour and Duke cherries, both in regard to the number of flowers and varieties used, is comparatively small, and consequently we hesitate to make any general statement with regard to the results they have given. But in the Sweet × Sour and Sweet × Duke and

reciprocal pollinations the number of flowers used is large and the differences in the proportions of fruit set in the reciprocal pollinations between these groups is considerable. The reason for these reciprocal differences is not at present clear, but we will tentatively consider the probabilities of hybridity and sterility involved.*

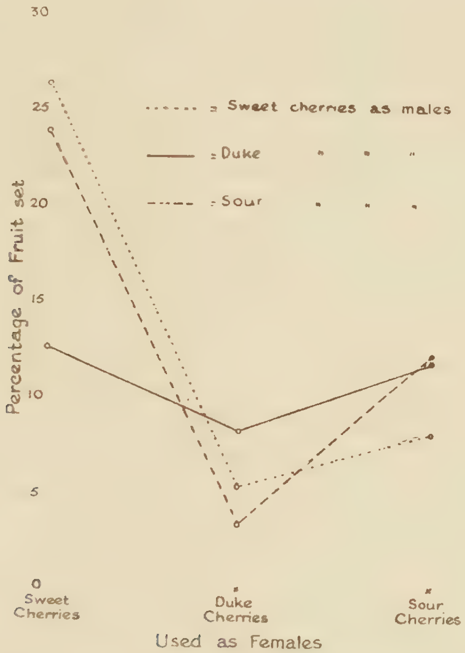

FIG. I.—INTERSPECIFIC FERTILITY IN CHERRIES.
Showing the percentage of fruit set in pollinations between varieties of *P. avium*, *P. cerasus* and the hybrid Duke Cherries.

Darlington (1928) has shown that the Duke cherries are tetraploids and that they have probably arisen in an exceptional way from hybridisation between the approximately diploid Sweet cherries and the tetraploid Sour cherries. If such be the case, then the immediate hybridity of the Dukes will be much greater than that of the varieties of *P. avium* and *P. cerasus*—the Sweet and Sour cherries respectively—and a corresponding difference in sterility might be expected.

Examination of the figures in Table IV. and their graphical presentation in Text Figure I. substantiates this premise, for not only do the Sour and Sweet varieties show a considerably greater fertility than the Duke varieties, but in

* When the tetraploid Dukes and Sour Cherries are used as females the endosperm, following triple fusion, will be pentaploid. When however the sweet Cherries are used as females the endosperm will be tetraploid. Possibly this may be associated with the differences in the proportion of fruit set in the reciprocal pollinations between these groups.

reciprocal crosses with Sweet varieties a striking parallelism is shown, e.g., the difference between the percentage of fruit set in (a) Sweet × Sour and Sour × Sweet, and (b) Sweet × Duke and Duke × Sweet, is strictly proportional.

The results of these experiments lead to the conclusion that in stone fruits fertilisation is essential for fruit development, but a subsequent breakdown in embryonic growth frequently occurs—particularly in cherries. This breakdown may result from several causes, the most probable of which is a discordance (a) of the parental chromosome contributions to the nucleus and endosperm of the zygote or (b) between the nucleus and endosperm. The consequence of these inharmonious relations is seen in the degree of the development of the embryo and the resulting bad and non-viable seeds. Some fruits at maturity contain but shrivelled testas, and others only partially developed embryos. Of a total of 4,513 cherry stones examined in the course of this work, only 59 per cent. contained apparently good seeds. The others showed various degrees of degeneration, and in 13 per cent. only the testas remained.

PLUMS.

Our domestic plums may be classified in one or another of the following classes :

1. Those which are self-compatible and set a full crop with their own pollen.

2. Partially self-compatible varieties. In this class there is considerable variation, some set very few fruits whilst others set a moderate crop when selfed, but all produce heavier yields when crossed with compatible varieties.

3. Self-incompatible varieties, which fail entirely with their own pollen.

The varieties used in these experiments and the results obtained from self-pollinations are given in Table V.

CROSS-INCOMPATIBILITY.

Among our established varieties of plums, comparatively few examples of cross-incompatibility have been found. The varieties involved in cross-incompatibiity and the groups in which they occur are as follows :

Group I.	*Group II.*	*Group III.*
Coe's Golden Drop	President	Rivers' Early Prolific
Coe's Violet	Late Orange	*Blue Rock*
Crimson Drop	*Cambridge Gage*	
Jefferson		
Allgrove's Superb		

TABLE V.

Self-compatible Varieties.

Variety.	No. of Flowers self-pollinated.	No. of Fruits set.	Percentage.
Golden Transparent	408	288	70.5
Denniston's Superb	630	398	61.1
Early Mirabelle	422	240	56.8
*Myrobalan Red	76	43	56.5
Early Transparent.	1,152	594	51.5
Oullin's Golden Gage	167	76	45.5
King of the Damsons	246	110	44.7
Monarch	19	6	31.5
Prince of Wales	1,251	390	31.1
Golaith	883	260	29.4
Gisborne's	1,681	420	24.9
Victoria	8,273	2,007	24.2
Prosperity	100	24	24.0
Guthrie's Late	1,541	367	23.8
Reine Claude de Bavay	26	6	23.0
Pershore	197	38	19.2
White Magnum Bonum	1,220	184	15.0
Purple Pershore	883	127	14.3
Belle de Louvain	675	92	13.6
Black Diamond	85	10	11.7
Prune Géante	251	25	9.9
Partially Self-Compatible Varieties.			
Farleigh Damson	2,384	109	4.5
Belgian Purple	1,015	43	4.2
*Yellow Myrobalan	3,067	110	3.5
Rivers' Early Prolific	22,901	746	3.2
Utility	1,092	31	2.8
Early Orleans	952	25	2.6
Cambridge Gage	3,588	54	1.5
Blue Rock	2,058	24	1.1
Cox's Emperor	932	10	1.0
Self-Incompatible Varieties.			
Crimson Drop	470	1	0.2
Transparent Gage	1,222	3	0.2
Yellow Magnum Bonum	491	1	0.2
Coe's Golden Drop	1,510	2	0.1
McLaughlin's Gage	887	1	0.1
Decaisne	648	1	0.1
Frogmore Damson	1,536	2	0.1
Late Orleans	4,727	1	0.02
Allgrove's Superb	241	0	—
Bryanstone Gage	594	0	—
Coe's Violet	733	0	—
Comte d'Althan	478	0	—
Early Greengage	1,312	0	—
Jefferson	421	0	—
Kirke's Blue	1,133	0	—
Late Orange	800	0	—
Old Greengage	386	0	—
President	883	0	—
Primate	36	0	—
Prune d'Agen	400	0	—
Pond's Seedling	932	0	—
White Damson	6	0	—
Golden Esperen (male sterile)	No pollen.	0	—

* Varieties of *P. cerasifera*.

All the individuals in Group I. and Late Orange and President in Group II. are wholly self- and cross-incompatible within their respective groups. Cambridge Gage sets occasional fruits when its own pollen and that of its co-incompatibles are put upon it. When used as male, however, it sets a full crop on the other two varieties.

Similar differences in reciprocal pollinations occur in Group III. where, although only occasional fruits set when pollen of Rivers' is put on to Blue Rock, the reciprocal pollination sets a full crop. Both Rivers' and Blue Rock set a few fruits when selfed.

It is worthy of note that, so far as we know at present, cross-incompatibility only occurs between varieties which are themselves self-incompatible or nearly so. Pollen of self-compatible varieties is always effective on self-incompatible kinds.

A summary of the results from pollinations made in the plums is given in Table VI.

TABLE VI.

		No. of Flowers pollinated.	No. of Fruits set.	Percentage.
Self-incompatibles	selfed ..	22,205	17	0.07
Cross-incompatibles	crossed ..	6,805	12	0.17
Partial compatibles	selfed ..	32,538	933	2.8
Partial compatibles	crossed ..	1,570	45	2.8
Compatibles	selfed ..	25,500	5,752	22.5
Compatibles	crossed ..	39,121	11,256	28.7

Although the compatibles crossed have set a higher proportion of fruit than the compatibles selfed, the latter have set abundantly, e.g., see Plate 2. Rawes (1922) has reported upon a number of plums, and his results are in close agreement with ours.

Golden Esperen is the only estabished variety of plum that we have found to be totally male sterile, but Florin (1927) describes another, "Allmänna gulplommon."

APPLES.

The results obtained from self-pollinating forty varieties are detailed in Table VII.

From the results detailed in Table VII. it is evident that variation in self-fruitfulness in the apple is practically continuous, contrasting sharply with that of the cherry, and differing appreciably from that of the plums. Nevertheless it is clear that incompatibility is largely responsible for the low percentage of fruit that many varieties set following self-pollination, as these varieties have

all cropped heavily when suitably cross-pollinated. In our experience, the varieties which have matured 5 per cent. of fruit with their own pollen have given the equivalent of a good crop.

TABLE VII.

Variety.	Flowers.	Fruit.	Percentage.
Gascoigne's Scarlet	47	0	0
Grime's Golden	36	0	0
Royal Jubilee	1,017	1	0.09
Brownlee's Russet	618	1	0.16
Northern Greening	940	2	0.21
Blue Pearmain	436	3	0.67
Duke of Devonshire	229	2	0.87
Encore	344	3	0.87
Blenheim Orange	640	6	0.93
Cox's Orange Pippin ..	8,142	77	0.94
Lady Sudeley	197	2	1.01
King's Acre Pippin	370	4	1.09
Worcester Pearmain	858	12	1.3
Lane's Prince Albert	3,218	48	1.4
Newton Wonder	334	5	1.4
Beauty of Bath	1,795	30	1.6
King of the Pippins	522	10	1.9
Norfolk Beauty	210	4	1.9
Winter Ribston	1,018	20	1.9
Ribston Pippin	336	8	2.0
Annie Elizabeth	294	6	2.0
Lord Derby	646	14	2.1
Peasgood's Nonsuch	173	4	2.3
St. Edmund's Russet ..	971	23	2.3
Charles Ross	289	7	2.4
Grenadier	200	5	2.5
Bismark	180	5	2.7
Golden Spire	1,947	67	3.4
St. Everard	481	19	3.9
Lord Grosvenor	250	11	4.4
Rev. W. Wilks	1,371	69	5.0
Washington	1,232	63	5.1
Bramley's Seedling	1,163	61	5.2
Crimson Bramley	439	23	5.2
Sturmer Pippin	135	7	5.2
Antonowka	388	28	7.2
Red Winter Reinette	226	17	7.5
Stirling Castle	1,631	131	8.0
Cellini Pippin	160	14	8.7
Coronation	143	19	9.6

Examination of the fruits obtained from self-pollination usually reveals but few good seeds, and often none at all, shrivelled and empty testas alone occurring. In some fruits there has been no embryonic development, e.g., Duchess of Oldenburg, Golden Spire, Lord Derby and Charles Ross commonly produce parthenocarpic (seedless) fruits. Fruits resulting from certain crosses have also contained but few good seeds. Thus in spite of incompatibility and generational sterility, a percentage of fruits may mature from self- and cross-pollinations. This makes any precise analysis of these phenomena in apples

difficult, the usual clearly defined expression of incompatibility being obscured by the modifying influence of varying degrees of generational sterility and parthenocarpy.

The best measure of fertility and incompatibilty in apples is doubtless provided by the number of viable seeds per fruit. In the earlier years of these experiments unfortunately details of the number and condition of the seeds were not recorded, but in Table VIII. some of our more recent results are given.

Each fruit has, potentially, ten seeds ; a few varieties, e.g. King of the Pippins and Duchess' Favourite, frequently have more than ten, the latter variety often having four seeds in each carpel instead of two. The seeds examined were divided into three classes, (1) apparently good (2) poorly developed, shrivelled and almost empty testas—" bad seeds " in Table VIII., and (3) minute remnants of undeveloped embryos. Class 3 is not represented in the Table but can be ascertained from the figures given.

TABLE VIII.

Apples : Self-Pollinated.

Variety.	Flowers	Fruit.	No. of good seeds.	No. of good seeds per fruit.	Bad seeds.	No. of seeds germinated.	Viable seedlings.	Viable Seedlings per fruit.
Rev. W. Wilks	983	55/49‡	110	2.2	27*	80	46	0.9
Crimson Bramley ..	205	8	17	2.1	9	—	4	0.5
Antonowka	131	9	18	2.0	0	—	14	0.6
Blenheim Orange ..	394	6	11	1.8	6	3	—	—
Winter Ribston	525	7/3	5	1.6	6	3	—	—
King's Acre Pippin ..	370	4	6	1.5	3	0	0	0
Baldwin	Many	109	174	1.5	159	—	16	0.1
Lord Grosvenor	250	11	15	1.4	3	5	1	0.09
Blue Pearmain	236	3	4	1.3	3	—	1	0.3
Encore	132	3	4	1.3	0	—	3	1.0
Cellini Pippin	160	14	16	1.1	5	—	5	0.3
Duke of Devonshire ..	229	2	2	1.0	3	—	—	—
Cox's Orange Pippin ..	2,982	34/32	25	0.7	31	13*	10	0.7
Stirling Castle	873	68	49	0.7	—	—	23	0.3
Lane's Prince Albert ..	2,173	34	10	0.3	35	6†	—	—
Golden Spire	651	32	10	0.3	2	7	7	0.2
Northern Spy	356	20	5	0.2	3	—	4	0.2
Charles Ross	289	7	1	0.1	0	1	—	—
Lord Derby	606	10	0	0.0	0	—	—	—
Royal Jubilee	150	1	0	0.0	0	—	—	—
Brownlee's Russet ..	324	1	0	0.0	0	—	—	—
Peasgood Nonsuch ..	173	4	0	0.0	0	—	—	—
Totals		/430	484	1.1%				

* Only 16 good seeds (from 13 fruits) were sown.

† Only 10 good seeds (from 7 fruits) were sown.

‡ 55/49=55 fruits set, of which only 49 were examined.

In no case has any variety averaged more than two apparently good seeds when selfed and of the seeds which set many failed to germinate. The most fertile variety tested was the Rev. W. Wilks, and although 72.7 per cent. of the good seeds of this variety germinated, the final number of seedlings is forty-nine, or less than one seedling per fruit Exceptions occur, but the large majority

TABLE IX.

Seeds from Cross-Pollinated Apples.

Variety.	Flowers	Fruits.	Good seeds	Good seeds per fruit.	Bad seeds.	No. of seeds germinated.	Viable seedlings.	No. of viable seedlings per fruit.
DIPLOIDS × DIPLOIDS.								
Golden Spire × Beauty of Bath ..	61	10	76	7.6	7	70	70	7.0
Royal Jubilee × Northern Greening	70	10	64	6.4	8	45	45	4.5
Royal Jubilee × Lane's Prince Albert	62	10	54	5.4	30	35	34	3.4
Encore × King's Acre Pippin ..	12	3	17	5.6	?	10	10	3.3
Brownlee's Russet × Rev. W. Wilks	94	2	11	5.5	5	—	—	—
Cox's Orange Pippin × Rev. W. Wilks	132	9	42	4.6	12	34	33	3.6
Cox's Orange Pippin × Stirling Castle	45	7	36	5.1	14	?	4	.5
Sturmer Pippin × Cox's Orange Pippin	130	14	82	5.8	?	?	40	2.8
Cox's Orange Pippin × Sturmer Pippin	300	26	86	3.3	58	?	42	1.6
DIPLOIDS × DIPLOIDS.								
Cox's Orange Pippin × Lane's Prince Albert	257	26/21	57	2.7	77	10 sown 8	—	—
Lane's Prince Albert × Cox's Orange Pippin	352	22	35	1.6	71	27 sown 26	—	—
Winter Ribston × Cox's Orange Pippin	101	14/10	26	2.6	33	10	2	.2
Winter Ribston × Encore	56	6	11	1.8	16	7	6	1.0
Cox's Orange Pippin × Newton Wonder	150	14	33	2.2	34	?	14	1.0
Cox's Orange Pippin × Peasgood's Nonsuch	89	10	29	2.9	43	28 sown 28	—	—
Cox's Orange Pippin × St. Everard	160	10	8	.8	46	6	—	—
Lane's Prince Albert × Charles Ross	159	10	4	.4	16	—	—	—
DIPLOIDS × TRIPLOIDS AND RECIPROCAL.								
Blenheim Orange × Cox's Orange Pippin	182	7	24	3.4	13	13	—	—
Cox's Orange Pippin × Blenheim Orange	454	40/34	36	1.0	139	26 sown 17	—	—
Bramley's Seedling × Cox's Orange Pippin	Many	7	0	0.0	33	—	—	—
Cox's Orange Pippin × Crimson Bramley	180	18/17	24	1.4	56	—	13	.7
Norfolk Beauty × Crimson Bramley	147	2	1	.5	0	—	—	—
Peasgood's Nonsuch × Blenheim Orange	42	2	4	2.0	1	2	—	—
Lane's Prince Albert × Blenheim Orange	220	20/19	55	2.8	39	52 sown 42	—	—

of seedlings raised from selfing apples lack vigour and many are stunted and deformed. Details of twenty-two varieties are given in Table VIII., and from 430 fruits only 484 apparently good seeds were obtained ; from 453 of these seeds, 134 trees have been raised, or only 0.37 per fruit. It seems clear, therefore, that a high degree of incompatibility prevails in the apple and that even in those varieties which have a high degree of self-fruitfulness only a low percentage of seeds develop from self-pollination.

Stout (1925) has shown that certain species of *Malus* are self-incompatible but produce fruit freely when cross-pollinated.

In Table IX. seed-production and fertility following cross-pollination are presented. The crosses made are separated into three groups, (1) diploid crosses giving good results, (2) diploid crosses giving poor results, and (3) triploid-diploid crosses. An account of triploidy in apples is given later in this paper. See page 296.

In the first of these groups the average increase as compared with self-pollination is five times the number of seeds per fruit and nine times the number of viable seedlings. Reciprocal crosses do not always seem to behave similarly, and in certain instances in the second group the results of crossing are no better than those of selfing.

The triploid-diploid crosses, as expected, show very poor seed development. The majority of the seventy-two seedlings raised,* are of recent origin and too young to include in the viable seedlings column, but at their present stage of growth, they are very weakly.

Triploid plants are generally sterile and unfruitful. Bramley's Seedling is a notoriously good cropper, however, and in order to throw further light on this unusual phenomenon sixty fruits from trees growing in the open ground were examined for their seed content. The results are given in Table X.

TABLE X.

Open Pollination of Bramley's Seedling.

Fruit size.	Seeds.				Total.
	Plump	Partially shrivelled	Badly shrivelled.	Empty testas.	
20 Large	40	20	13	61	134
20 Medium	21	15	16	70	122
20 Small	19	20	15	61	115
Totals	80	55	44	192	371

* During 1928 more than a dozen of these have died.

The results are strikingly uniform for the three classes, except that there is an obvious correlation between large size and the number of good seeds. It seems probable that the difference in size between the medium and small fruits is a fluctuation governed by nutrition.

The potential seed content of sixty apples in 600 seeds, but Bramley's from open pollination have given only 1.3 good seeds per fruit. The plump, partially shrivelled and badly shrivelled seeds have been sown to secure further information with regard to triploidy.* Triploidy and pollen sterility in apples is discussed later (p. 296).

INCOMPATIBILITY.

The occurrence of self- and cross-incompatibility in plants has long attracted the attention of biologists.

Correns (1912-1913) first applied the methods of genetic analysis to the problem. He was followed by a number of workers amongst whom East and his collaborators (1925-26), Lehmann (1926) and Sirks (1926) after many years of extensive experiments arrived independently at conclusions which are fundamentally the same.

The above investigators' experiments have shown that incompatibility is determined by genetic factors just as are morphological characters. Following East's terminology these factors designated by the letter S form a multiple series S_1, S_2, S_3, etc. and in a manner similar to other Mendelian factors any two of these may be carried by a given plant.

Pollen *cannot* function in the style of a plant carrying the same incompatibility factors as the pollen. "Like repels like." Self- and cross-pollination between individuals with the same genetic constitution with respect to incompatibility factors fail because the growth of the pollen tubes is arrested in the nutrient stylar tissue. Consequently groups of individuals occur within which all cross- and self-pollination fail. Individuals also occur in which the reciprocal crosses differ. Thus as individual of the constitution S_1S_2 cannot be fertilised by S_1 or S_2 pollen (Fig. 2A). On the other hand in the cross $S_1S_2 \times S_3S_4$ both S_3 and S_4 pollen can penetrate the style of the mother and effect fertilisation (Fig. 2C). The offspring from such a cross will consist of four intra-sterile inter-fertile groups of the constitution S_1S_3, S_1S_4, S_2S_3 and S_2S_4. When a plant carrying S_1S_2 is pollinated with an S_1S_3 individual (Fig 2B) the S_3 pollen alone fertilises the S_1 and S_2 ovules of the female plant to give rise in the next generation to two intra-sterile inter-fertile groups of plants of the constitution S_1S_3 and S_2S_3. In this cross the S_1 pollen fails to function because the mother plant also carries S_1. The S_1S_3 group will be reciprocally incompatible with the male parent as they are

* 22.4.29. From the large fruits 40 seeds germinated, from the medium 48 and from the small 6.

of the same genetic constitution with respect to these physiological incompatibility factors. All other combinations between parents and F_1 will be compatible.

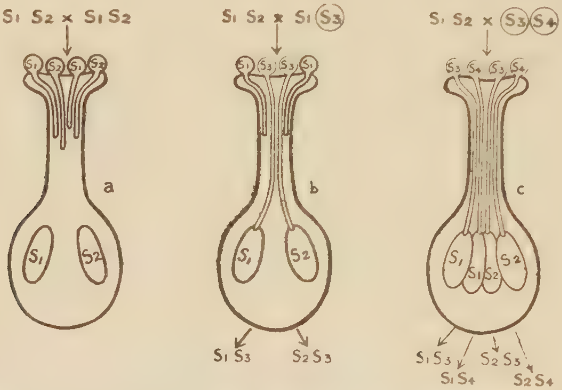

FIG. 2.—COMPATIBLE AND INCOMPATIBLE POLLINATIONS.

Previous to this genetic interpretation of incompatibility Prell (1921) had suggested a solution which closely accords with facts. Prell derived his solution from the published work of others.

The breeding of fruit trees and especially the testing of seedlings with respect to incompatibility is a prolonged process. Our results with seedlings are for the present withheld, but as far as our investigations with the sweet cherry have gone, both with seedlings and established varieties, there is nothing which conflicts with the above workers' interpretation. An analysis of our results in plums, however, reveals further complications, e.g. partial self- and cross-compatibility, unexpected differences in reciprocal pollinations and self-compatibility. The genetic relation of self-compatibility with self-incompatibilty is not at present clear even in diploid plants, and since our domestic plums are hexaploids, the solution may naturally be more complex. In our breeding experiments with plums unusual segregation has been observed. (Crane, 1921).

In polyploid plants exhibiting incompatibility the gametes will carry more than one factor for incompatibility, and the possibility of the occurrence of interactions favourable to greater variation in pollen tube growth must be considered. For example two tetraploid plants of the constitution ($S_1S_1S_2S_3$) and ($S_1S_1S_2S_2$) might present different inhibitory effects to (S_2S_3) pollen. Consequently varying degrees of incompatibility might reasonably be expected, and it is noteworthy that the phenomenon of incompatibility appears to be less complex in the approximately diploid cherries than it is in the tetraploid cherries and hexaploid plums. Probably the comparatively few examples of cross-incompatibility so far observed in varieties of our domestic plums is due to the same cause.

It should be emphasised that incompatibility has a genetic basis and is the expression of the interaction of particular factors ; co-incompatible plants may be quite different morphologically, *e.g.* the cherries Bigarreau de Schrecken, Bigarreau Frogmore, Belle Agathe and Waterloo are all in the same incompatible group, although they differ widely in fruit colour and in many other respects.

POLYPLOIDY, STERILITY AND FRUIT PRODUCTION.

From a genetic point of view a plant is a double structure resulting from the fusion of the nuclei of two germ-cells—a pollen grain and an ovule. Hence the somatic or body cells of a plant result from the addition of the parental germ-cells, and in order to repeat this process in their own reproduction it is necessary that corresponding elements derived from the parental germ-cells should separate. If the parental germ-cells themselves did not correspond then this process can not be carried out in an orderly way and sterility results.

In the majority of plants the body cell nucleus contains two sets of corresponding chromosomes which divide during the process of reproduction, forming germ-cells—pollen grains and ovules—each with one set of chromosomes. But this process of reduction is often complicated among our cultivated fruits owing to their hybrid origin and complex chromosome constitution. Instead of possessing two corresponding or homologous sets of chromosomes many are polyploid, that is to say they possess more than two sets. Those with an even number, such as tetraploids with four sets, hexaploids with six and octoploids with eight, are usually more productive than those having an odd number of sets, such as triploids with three, pentaploids with five and heptaploids with seven sets. Apart from other considerations it is obvious that an odd number cannot divide evenly and consequently irregularities and sterility will inevitably follow.

A brief consideration of some of our cultivated *Rubi*, which have been cytologically studied by our colleague, Dr. C. D. Darlington, will demonstrate the importance of polyploidy in relation to sterility and fruit production. In *Rubus* the basic chromosome number is seven. The raspberry varieties, " Superlative " and " Lloyd George," have fourteen chromosomes, the " Mahdi " twenty-one, the " Veitchberry " twenty-eight, the " Loganberry " forty-two, and the " Laxtonberry " forty-nine, and it is well known that the fertility and fruit production of the odd multiple forms, the triploid Mahdi and the heptaploid Laxtonberry is much lower than that of the even multiples and balanced chromosome forms, the diploid raspberries, the tetraploid Veitchberry and the hexaploid Loganberry. Longley (1926) has studied many of the American horticultural forms of *Rubi* and has shown that those which possess an odd multiple of seven produce very little good pollen and are highly sterile, but that the even multiples have comparatively little sterile pollen.

These facts show that fertility in *Rubus* is associated with a balanced chromosome constitution. Certain exceptions to this rule are probably due to the apogamous development of seed. The possibilities of obtaining fertile progeny from crossing in this genus are also largely limited by the purely numerical relations of their chromosome complements. For example the offspring from a diploid crossed tetraploid will be triploid, and those from a tetraploid crossed hexaploid will be pentaploid, but occasionally exceptional seedlings arise from such a cross, as shown by the following instances. When we crossed *Rubus rusticanus inermis* a diploid species with fourteen chromosomes with *Rubus thyrsiger* a tetraploid species with twenty-eight, we obtained three seedlings, two of which were triploids arising from the addition of seven *rusticanus* and

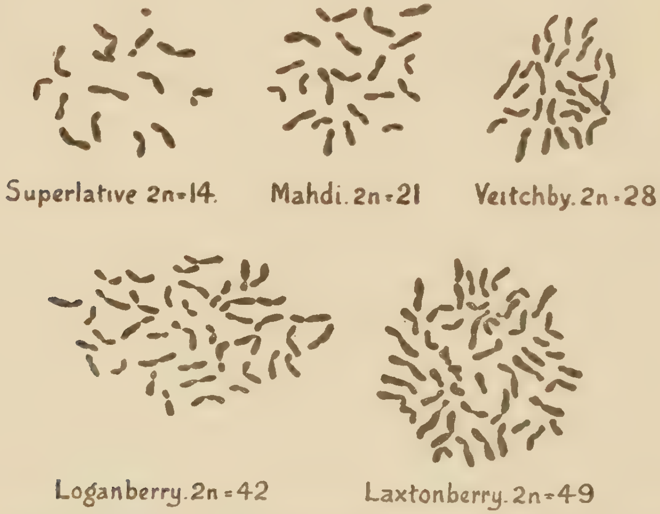

FIG. 3.—SHOWING THE CHROMOSOME COMPLEMENTS OF DIPLOID AND POLYPLOID *Rubi*.

fourteen *thyrsiger* chromosomes, the haploid or reduced number of each species. The other seedling had twenty-eight chromosomes and arose by the functioning of an unreduced egg of its mother whereby the full chromosome complement of *rusticanus* (fourteen) combined with the haploid complement of *thyrsiger*, also fourteen, giving rise to a tetraploid plant with twenty-eight chromosomes. This tetraploid seedling is highly fertile and very productive, whereas the triploid seedlings set only occasional drupels. The "Veitchberry" and "Laxtonberry" have also evidently originated from the functioning of a gamete with the unreduced number of chromosomes* (Crane and Darlington, 1927). From

* The Laxtonberry was derived from the Loganberry × Superlative Raspberry and has 49 chromosomes; doubtless the full complement of the Loganberry (42) combined with the haploid complement (7) of the Raspberry.

families of cherries we have raised, (Darlington, 1928) has also shown that the "Dukes" cherries, which have thirty-two chromosomes, have probably arisen from the Sweet cherry (with sixteen) and the Sour cherry (with thirty-two) by the same kind of irregularity.

In *Prunus* the basic chromosome number is eight. Ewert (1922), Knowlton (1924), Kobel (1927), Darlington (1926-8). The somatic number of our commoner species is as follows :—

Prunus	*cerasifera* (Myrobolan plum)	16
,,	*spinosa* (Sloe)	32
,,	*insititia* (Damson)	48
,,	*domestica* (European plum)	48
,,	*persica* (Peach)	16
,,	*mahaleb* (St. Lucie Cherry)	16
,,	*avium* (Sweet Cherry)	16+
,,	*cerasus* (Sour Cherry)	32
,,	*cerasus* × *avium* (Duke Cherry)	32

The above fertile forms of Prunus have a balanced diploid, tetraploid or hexaploid chromosome complement. But our cultivated varieties of *P. avium*, the sweet cherry, are exceptional in sometimes having one or more chromosomes beyond the diploid number.

Hybrids we have raised from *P. domestica* (forty-eight) crossed *P. cerasifera* (sixteen) and from *P. insititia* (forty-eight) crossed *P. spinosa* (thirty-two) have the intermediate chromosome number expected, i.e., thirty-two and forty. These seedlings are as yet too young to determine their degree of fertility. It is of interest to recall that the pollinations we have made between *P. domestica* and *P. insititia*, both hexaploid, have always been completely inter-fertile. But from pollinations between diploid and polyploid and different polyploid forms, such as *P. domestica* crossed *P. cerasifera* and from *P. insititia* crossed *P. spinosa*, fruits with viable seeds are but rarely formed. In the American plums Dorsey (1919) found that the percentage of aborted pollen was higher in hybrids than in species.

As far as is known triploid varieties of *Prunus* are only found as ornamental varieties, their degree of sterility being too high to enable them to be grown for their fruits, e.g. *P. nana* (Darlington, 1928) and Japanese cherries (Okabe, 1928). In families we have raised between forms of cherries with thirty-two and sixteen chromosomes a high degree of sterility was common, probably owing to an unbalanced triploid chromosome complement. Some of these seedlings have been examined and found to have twenty-four chromosomes.

Longley (1926) found the basic chromosome complement of the strawberry (*Fragaria*) to be seven.

The wild European strawberry (*F. vesca*) has fourteen chromosomes. The other species, including our modern cultivated varieties, are found to be polyploids. Thus *F. elatior* (the Hautbois strawberry) has forty-two, *F. virginiana* fifty-six and *F. chiloensis* fifty-six chromosomes. All three of the polyploid species have much larger fruits than the diploid *F. vesca.*

The work of Ichijima (1928) and Mangelsdorf and East (1927) confirms and extends the findings of Longley. Five diploid forms (including *F. vesca*) hybridised freely and gave fertile progeny. Similarly crosses between octoploids gave fertile offspring. Attempts to intercross species with different chromosome numbers were often abortive or at the most only resulted in sterile hybrids.

One plant of considerable interest arose from a cross between two diploids. This individual had twenty-eight chromosomes instead of the expected fourteen, and moreover bred true to type instead of segregating and recombining the characteristics of the parents. These tetraploid plants may be considered therefore to be representatives of a new species—none of which is known to exist in nature.

It is significant that our cultivated strawberries are also octoploids. The rapid development of the strawberry subsequent to the introduction into Europe and cross breeding of the two octoploid species *virginiana* and *chiloensis* is well known, and there is little doubt that these species were the immediate parents of our modern varieties. Crosses are readily made between the two octoploid species, but have rarely been secured between species with dissimilar chromosome numbers.

In *Ribes* the basic chromosome number is eight, and as far as is known, although many species have been cytologically studied, polyploidy does not occur within the genus (Tischler, 1927-8, Meurman, 1925 and 1928, Darlington, 1927 and 1929).

In grapes Nebel found that the varieties Muscat Gigas and Sultanina Gigas were tetraploid forms, their somatic chromosome number being 76. Apparently these tetraploids are larger than diploid forms. Nebel also made the interesting observation that Muscat Gigas (tetraploid) has six satellites, whereas Muscat (diploid)has only three.

Longley (1927) in a a cytological investigation of the number of chromosomes in the Blueberry, *Vaccinium* species and hybrids, found three diploid, six tetraploid one pentaploid and two hexaploid forms. The basic chromosome number is 12. Coville (1927) in the same genus found that he could inter-cross species with the same chromosome number, but crosses between forms with a different number of chromosomes failed or produced highly sterile offspring.

In the cultivated fruits so far discussed, we have shown that, except for the sweet cherries which have one or more chromosomes in excess of the diploid number, the really productive forms have a balanced chromosome complement, and that those with an odd multiple and unbalanced chromosome constitution

are generally unproductive. Although a certain amount of bad pollen and ovules is evident in the productive varieties, nevertheless they have a sufficient proportion of good ovules and pollen to ensure, under favourable conditions, an abundant yield.

As a preliminary to a cytological study of our cultivated varieties of apples we have determined the somatic chromosome numbers from the root tips of the following varieties. For trees growing on their own roots—invaluable material for these studies—we are indebted to the Director of the East Malling Research Station.

Variety.	*Chromosome Number.*	*Variety.*	*Chromosome Number.*
Allington Pippin	34	Northern Spy	34
Annie Elizabeth	34	Oslins	34
Beauty of Bath	34	Newton Wonder	34
Bramley's Seedling ..	51	Lord Derby	34
Blenheim Orange	51	Rival	34
Carlisle Pippin	34	Reinette Zuccamaglio ..	34
Cox's Orange Pippin ..	34	Winter Majetin	34
Early Victoria	34	Worcester Pearmain ..	34
Genet Moyle	51	APPLE STOCKS,	
Grenadier	34	Old English Broadleaf (Malling Type I) ..	34
Irish Peach	34	Doucin (Malling Type II) ..	34
Keswick Codlin ..	34	Jaune de Metz (Malling Type IX)	34
Kentish Codlin	34	Nonsuch (Malling Type VI)	34
Lane's Prince Albert ..	34		
Manx Codlin	34		

FIG. 4.

Chromosome Complements of (A) Worcester Pearmain 2n-=34.
(B) Blenheim Orange, 2n=51.

These varieties are being studied further by Mr. A. A. Moffett, in collaboration with Dr. C. D. Darlington.

From the published results of other investigators and the above list, it appears that the basic chromosome number in the genus *Pyrus* is seventeen. In

addition to Blenheim Orange, Bramley's Seedling and Genet Moyle listed above, Rybin (1927) has shown that Reinette de Canada is another triploid, and from Kobel's (1927) publication the following varieties appear to be triploids, viz., Warner's King, Ribston Pippin, Gravenstein, Baldwin.

The studies of several workers show that irregularity of divisions in the pollen mother cells is prevalent to a considerable degree (Shoemaker 1926, Rybin 1926, 1927, Kobel 1927, Heilborn 1928). The result of this irregularity is also seen in the percentage of good to bad pollen, the general occurrence of imperfect seeds and the low proportion of fruit setting and reaching maturity. In this respect the publications by Florin (1926) and Kvaale (1926) are noteworthy. Florin divided the varieties he listed for pollen germination into three classes, poor, medium and good. Excepting Genet Moyle, which was not included in his tests, all the triploid varieties mentioned above are in his poor germination class. Kvaale in his germination tests found that the percentage of pollen germination of Baldwin was only 12.3, Ribston 21.4, Gravenstein 13, Bramleys 20.6, Warner's King 14.8. These are triploid varieties. On the other hand, if we refer to the varieties in his list now known to be diploids, we find that 96.5 per cent. of the pollen of Keswick Codlin germinated, 90 per cent. of that of Northern Spy, 69.3 of Cox's Orange and 52.1 of Newton Wonder, in all cases a much higher percentage than in the triploid varieties. It is possible that the diploid varieties with the lower percentage of good pollen are segregates from diploid-polyploid crosses, for in such diploids pairing would be accomplished only imperfectly or with difficulty, owing to the hybridity of the plant, *e.g.*, Ribston Pippin (a triploid) is frequently alleged to be one of the parents of Cox's Orange Pippin, which is a diploid with only a moderate amount of good pollen.

Apart from incompatibility, it is obvious that the higher the percentage of good pollen the greater the efficiency of the variety as a pollinator for other varieties.

That triploid forms and others showing high irregularities in germ-cell formation occur among our productive varieties of apples, is probably due to the greater number of ovules per fruit and the lower proportion of fruit to flowers required to give a satisfactory crop as compared with other tree fruits, *e.g.*, plums and cherries. To some extent parthenocarpy, the development of fruit without seed, has to be considered. Thus in apples an economic yield can be maintained in spite of a high degree of sterility.

It may be premature to speculate on the origin of the triploid varieties of apples, whether they have arisen from hybridisation between tetraploid and diploid forms or by the functioning of unreduced gametes. But so far no tetraploid varieties of cultivated apples are known, although tetraploidy occurs within the genus, *e.g.*, *P. Toringo* (Kobel 1927), *P. glaucescens*, *P. coronaria* (Nebel 1929).

Sterility in pears is apparently even more prevalent than in apples. Florin (1926) tested the pollen germination of 105 varieties, and found that 40 of these had an average germination below 30 per cent. as compared with 14 per cent. of the total number of varieties in the same class in apples.

He examined cytologically the variety Alexander Lucas and found the somatic chromosome number to be about fifty-six, presumably a hyper-triploid and he also found great irregularities in the reduction divisions.

Kobel (1927) in his studies examined seventeen varieties of pears, seven of which appeared to be approximately triploid and show a greater proportion of bad pollen than the diploid varieties. Within the diploids different proportions of good to bad pollen occur as in the diploid apples.

Osawa (1920) has shown that many varieties of the Mulberry are triploids and in breeding experiments he obtained a triploid from crossing diploid with diploid. In the triploid forms parthenocarpy is common. The basic chromosome number in the Mulberry is $n=14$.

The facts presented in this paper have referred to hybridity and polyploidy in relation to sterility and fruit production. Nevertheless it is evident that polyploidy has played an important and progressive part in the evolution of our domestic fruits. Increase in size and other desirable variations are often associated with polyploidy and hybridisation, *e.g.*, compare our cultivated octoploid strawberries, or even the polyploid species of *Fragaria*, with the diploid species.

The sterility associated with the offspring of wide crosses, such as that of the plum crossed peach, and the black currant crossed gooseberry, is well known. In such extreme crosses the two sets of chromosomes derived from the respective parents work in harmony throughout the somatic life of the hybrid, but are unable to pass successfully through the intricate processes of germ cell-formation. Such hybrids being totally or almost entirely unproductive are of but little interest to the fruit grower.

MORPHOLOGICAL STERILITY.

So far the form of sterility discussed in this paper has been due to gametic irregularities—abortive pollen or ovules, or to zygotic degeneration—the breakdown of embryonic growth. There is another form of sterility which occurs in fruit owing to the suppression or abortion of the sex organs. For example the anthers of the plum Golden Esperen are contabescent and contain no good pollen. Consequently although it is fertile on its female side and sets fruit freely when pollinated with other varieties it is uselesss as a pollinator for other varieties owing to the sterility of its male organs.

In peaches Connors (1926) has shown that the variety J. H. Hale and others are male sterile.

Male sterility is not uncommon among the many seedlings we have raised at Merton. In the breeding of commercial varieties of raspberries we have obtained four sexually distinct forms, hermaphrodite, female, male and neuter. In the latter both the male and the female organs are suppressed. The male forms of course never bear fruits ; but the females crop freely when pollinated by other individuals. Our results show that these sex forms in raspberries are the expression of genetic differentiation, the suppressed forms being recessive, and from crosses between them a close approximation to the expected Mendelian segregation is obtained.

In strawberries and in the cultivated grape aborted and suppressed sex organs commonly occur (Valleau, 1918), (Stout, 1921).

SUMMARY.

It is shown that three forms of " sterility " occur in our domestic fruits. (1) Generational sterility, (2) Morphological sterility, (3) Incompatibility.

Self-incompatibility is general throughout the sweet cherry, *Prunus avium*. Cross-incompatibility is also of frequent occurrence in this group. In the tetraploid cherries, *i.e.*, the sour cherry, *Prunus cerasus*, and the Dukes, there are varying degrees of self-compatibility.

Plums, varieties of *Prunus domestica*, may be classified as follows: (1) self-compatible, (2) partially self-compatible, (3) self-incompatible varieties. Cross-incompatibility has been found only in the last two of these classes. Pollinations between self-compatibles and self-incompatibles have always been effective. The expression of incompatibility is more complex in plums than in cherries, and comparatively few examples of cross-incompatibility have been found in established varieties of plums. It is suggested that these variations are due to the hexaploid chromosome constitution of the plums.

Incompatibility occurs in apples, but it is shown that generational sterility is present to a higher degree in these fruits than it is in cherries and plums.

Odd multiple polyploids are generally unfruitful, *e.g.*, triploid forms of *Rubus* and *Prunus* are highly sterile. In apples, however, some of our most productive varieties are triploids, and produce fruit freely in spite of considerable generational sterility.

The relationship of polyploidy to sterility and fruit production and the genetical aspects of incompatibility are discussed.

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THE WILT DISEASE OF THE CARNATION.

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The Disease.

During recent years the damage caused by Wilt Disease has occasioned much alarm among carnation growers, and it is no exaggeration to say that it has reached such importance that the continuance of carnation growing is threatened in certain districts.

Considerable confusion exists in the minds of nurserymen and others concerning the nature of the disease, and it is commonly assumed that there are several diseases of different origins, some of which attack the root and others the aerial parts of the plant. These so-called separate diseases are all related by a common feature, viz, Wilt, and investigation has shown that they are all* due to the invasion of the plant by parasitic fungi.

These belong mainly to the genus *Fusarium*, to which the present investigation is confined, though it must be confessed that *Rhizoctonia* and *Sclerotinia* have been isolated in a few cases. Under very special conditions, *Botrytis* can also cause Wilt.

Fusaria capable of causing Wilt of carnations have a world-wide distribution, having been reported from France (5), Denmark (8), Czecho-Slovakia (12), Italy (1) and East (10) and South Africa (11), while the disease is said to be widespread in the United States of America (4). In this country the disease has been received from or known to exist in the counties of Bucks, Essex, Hampshire, Herts, Kent, Middlesex, Monmouth, Northumberland, Oxford and Yorkshire.

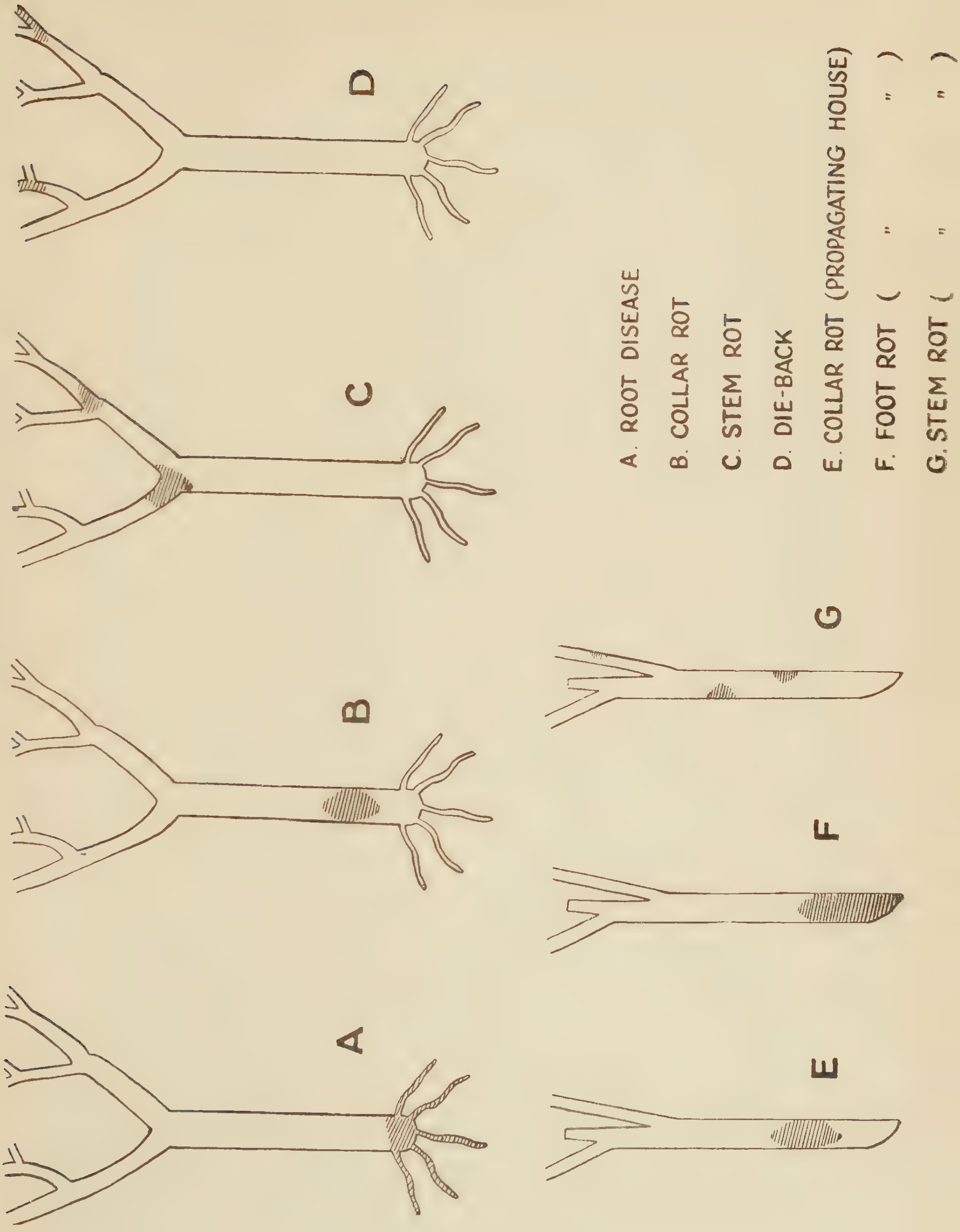
The examination of many hundreds of plants in commercial carnation nurseries reveals that while Wilt is a common feature, the plants are not attacked in the same position in all cases. Variation in the position of infected areas causes variation in the type of symptom following infection, and gives rise to the supposition amongst growers that there are several different diseases. The positions of the infected areas and the types of symptoms to which they give rise can conveniently be explained by the following classification. (Figure I.)

(*a*) *Root Disease.*

The root form is the most serious, because the soil becomes infected over a considerable area, and the plants, often at the height of the spring or summer

* Cases of physiological wilt, simulating that caused by Fusarium sometimes occur. First year plants of certain varieties, e.g. Peerless are especially susceptible and wilt from no obvious cause. Such plants are free from lesions but the pith may be dried and split at soil level.

FIG I


A
B
C
D
E
F
G
A. ROOT DISEASE
B. COLLAR ROT
C. STEM ROT
D. DIE-BACK
E. COLLAR ROT (PROPAGATING HOUSE)
F. FOOT ROT (" ")
G. STEM ROT (" ")

crop, wilt over large patches. In this case the roots are first infected, and show brown lesions which often extend into the aerial part of the stem before the plants wilt.*

(*b*) *Collar Rot.*

Wilted plants show a brown rot at soil level, between healthy stem and roots. Infection takes place at soil level.

(*c*) *Stem Rot.*

Characterised by a gradual development of Wilt which affects the plant limb by limb. Months may elapse before the plant is finally killed. The wood is infected at the junction of the main limbs with the stem of the plant.

(*d*) *Dieback.*

Infection of small shoots or snags left in cutting blooms is followed by the wilting of any " breaks " above the point of infection. The fungus grows back, discolouring the surface of the infected shoot, which becomes white and rough. It rarely grows back into the main stem, and under normal conditions has never been observed to cause the death of a plant.

The Wilt Disease in the Propagating House.

The commonest forms of the disease in the propagating house are Foot Rot, where infection has occurred through the exposed surface made in taking the cutting ; Collar Rot, where infection may usually be traced to a leaf-base below the level of the sand or compost ; and Stem Rot, where infection may be traced to a leaf-base above the level of the sand or compost. While isolations from wilted cuttings in commercial propagating houses have in some cases yielded the fungus responsible for the Wilt disease, in others no organisms have been found, and it is clear that much of the Wilt in commercial propagation commonly attributed to disease is of physiological origin, and due to conditions unsuitable for rooting.

The Causal Organism and its Isolation.

Cultures of Fusaria were readily obtained by removing small pieces of browned tissue under aseptic conditions, and placing them on slopes of nutrient agar. Where it was thought that specific differences were present, single spore cultures were made, and after testing for pathogenicity the strains were grown under comparable conditions on Hard Potato Agar + 3 per cent. Glucose, Steamed Rice, Steamed Carnation Stems, and a synthetic medium recommended by Brown (3). A comparison of the characters used for the identification of Fusaria indicated different species. Examination of the

* It has been observed that comparatively sudden wilting of the whole plant follows root or collar infections. In cases of infection above ground the plant dies slowly limb by limb and the disease appears to make no progress for considerable periods.

cultures showed that no correlation existed between the different species and the types of lesions from which they had been isolated. The species were kindly identified by Dr. H. W. Wollenweber as follows:

Fusarium	*culmorum*	(W.G. Sm) Sacc.
,,	*anthophilum*	(A.Br.) Wr.
,,	*acuminatum*	Ell et Ev emend Wr.
,,	*herbarum.*	(Corda)
,,	*sporotrichoides*	(Sherb.)

Of these *F. culmorum* is by far the commonest, while *F. herbarum* has been obtained on one occasion only. *F. sporotrichoides* (Sherb.) was found causing bud-rot in a nursery on which the root-type of the disease caused by *F. acuminatum* was prevalent. Inoculations of *F. sporotrichoides* into buds of healthy plants caused bud-rot; others into the stem caused only a very slow wilt of two out of the six plants inoculated. The remaining four showed wood-lesions, extending from the point of inoculation, but had not wilted 123 days after inoculation. The above list is not claimed to be complete, and a more extensive investigation might reveal other Fusaria pathogenic to carnations.*

INOCULATION EXPERIMENTS.

(*a*) *Stem Inoculation.*

(a) Inoculations of *F. culmorum* by hypocotyl stabs were made (April 14th, 1926) on fifteen one-year-old Peerless plants on a bed in a commercial nursery. Thirteen intermediate plants were treated as controls.

Six inoculated plants showed Wilt on September 14th, 1926, and two of these were dead. Typical sporodochia of Fusarium had appeared on the stems of eight of the inoculated plants, including three that had not yet begun to wilt. Fusarium was readily isolated from the two dead plants, the lesions of which were similar in appearance to those of naturally infected plants. The thirteen control plants each situated between two inoculated plants showed no Wilt at the end of five months, and their stems were free from sporodochia.

(b) The results of inoculations made on one-year-old plants in pots, by pricking the fungus into the bases of the main limbs are shown in Table I.

With the exception of a few unidentified Fusaria isolated from roots, and probably of secondary origin, all the Fusaria tested have been found to be pathogenic. The period between inoculation and Wilt has been found to depend on the condition of the stem and point of inoculation, so that the rapid Wilt obtained in the series inoculated on April 27th, 1928 is attributable to the season of the year and the "sappiness" of the young plants used.

* At least one species different from those in the list above, *F. avenaceum*, has been isolated from carnations by Dr. W. J. Dowson, formerly of Wisley, together with *F. herbarum*.

TABLE I.

Date of Inoculation.	Inoculum.	Origin of Strain.	Number of Inoculations.	Number of Wilted Plants.	Average number of days from Inoculation to Wilt.	Re-isolations that gave Fusarium pure or nearly so.	Total Re-isolations made.	Appearance of sporodochia of same species as inoculum on inoculated stems.
31.7.26	*Fusarium culmorum*	Lesion at junction of main limbs ..	3	3	10	2	3	3
,,	,, ,,	Browned wood of wilted cutting ..	3	3	18	3	3	3
,,	,, ,,	Spores on shoot dying back	3	3	21	1	2	3
,,	,, ,,	Water supply of carnation nursery ..	3	3	13	0	3	3
,,	,, ,,	Lesion arising from root infection ..	3	3	19	1	3	2
,,	,, *anthophilum*	Lesion at junction of main limbs ..	3	2	24	0	2	1
1.8.26	,, *culmorum*	Spores from saprophytic growth on fallen bud	3	2	19	2	2	3
,,	,, *acuminatum*	Lesion at leaf-base	3	3	19	3	3	2
,,	,, *anthophilum*	Lesion at soil-level traceable to a wound	3	3	19	3	3	3
,,	,, *herbarum*	Spores from superficial lesion on stem of otherwise healthy plant ..	3	1	37	1	1	1
,,	Controls	.. ..	4	0	0	0	0	0
2.8.27	*Fusarium culmorum*	Lesion at soil level	3	3	14	0	2	0
,,	,, ,,	Decaying matter on path of carnation house	3	3	14	0	3	0
,,	,, *anthophilum*	Pith lesion	6	6	22	3	6	0
,,	,, *herbarum*		3	3	17	3	3	0
,,	,, sp.	Root lesions	3	No Wilt	0	0	0	0
,,	,, sp.	Root lesions	3	by 1.2.28	0	0	0	0
,,	Controls	.. ..	4	0	0	0	0	0
27.4.28	*Fusarium acuminatum*	Lesions of plants with root disease ..	9	9	8	9	9	0
,,	,, *culmorum*	Aster	6	6	5	6	6	0
,,	,, ,,	Chrysanthemum	6	6	6	4	4	0
,,	,, ,,	Tomato root	6	6	5	6	6	0
,,	,, *sporotrichoides*	Carnation bud rot	6	2	about 86	0	0	0
,,	Controls	.. ..	4	0	0	0	0	0

It may be noted that *Fusarium culmorum*, pathogenic to carnations, has been isolated from :

(1) Asters in a private garden previously grassland.

(2) Chrysanthemums (outdoor) in a field adjacent to a nursery.

(3) Tomato roots in a block of tomato houses at the Cheshunt Experimental Station.

In each of these cases no carnations had been grown at any time previously on the land.

B.—*Development of Dieback.*

(a) Young plants were "stopped" at about six joints, and a drop of a spore suspension of *F. culmorum* in sterile water was placed on the cut ends by means of a sterile glass rod.

No infection was obtained when the experiment was carried out in the normal atmosphere of a cool glass house. The experiment was repeated by inoculating shaded plants at different times during the day and late in the evening with negative results ; but infection followed the pricking of sporodochia into the cut ends of the stems of plants with a sterile needle.

(b) Six plants placed in a moist chamber were inoculated with spores of *F. culmorum* in dilute sterile carnation juice, placed on the cut ends of the stems with a sterile platinum loop. Four controls were left uninoculated. April 28th, 1927—date of inoculation.

May 2nd, 1927. Cut stems of control plants remained green. Cut stems of inoculated plants showed fungal growth and the ends were discoloured to a distance of 1 cm. from the point of inoculation. (See Plate 1, Fig. 2.) Plants were removed from the moist chamber and placed in a cool glass house for rest of season.

June 11th, 1927. Snags of control plants still green and healthy. Snags of inoculated plants browned as far as second joint.

In one variety "breaks" were formed at the first joint. These did not wilt for several months, but remained dwarfed while the corresponding "breaks" on the control plants extended normally.

July 21st, 1927. The inoculated shoots averaged 4.2 cm. in length ; the control shoots 26.8 cm.

September 23rd, 1927. Young "breaks" at top joints all wilted and Dieback had reached the third joint. The lower "breaks" on all the plants remained healthy, and the fungus made no further progress after this month, but died out.

The growth of the fungus in this experiment was similar to the course taken by Dieback in commercial nurseries, where detailed observations on

individual plants have shown that the disease rarely grows back fast enough to threaten the life of the plant.

(c) Eight young plants (variety Topsy) were "stopped" at six joints in the usual manner. Six were inoculated with spore suspensions of *F. culmorum* in sterile water and two served as controls. These plants were inoculated in the hot, humid atmosphere of a cucumber house, in which the plants remained until the conclusion of the experiment.

The following observations were made on one of the inoculated plants. Similar observations were made on the remaining five inoculated plants :

May 13th, 1927. Date of inoculation.

May 16th, 1927. Pink fungal growth on cut end.

May 18th, 1927. Cut end of stem "eaten" away and covered with fungal growth.

May 27th, 1927. Surface of stem below first joint coloured white, and lesions on the leaf-bases where they are in contact with the fungal growth on the stem.

June 3rd, 1927. Discoloration completely girdled the stem below the first jont, and wilt of a young "break" at that joint.

June 11th, 1927. Stem discolored as far as second joint and covered with fungal growth.

June 18th, 1927. Discoloration, fungal growth, and sporodochia as far as third joint.

June 22nd, 1927. Dieback has reached the fourth joint.

June 4th, 1927. Plant beyond recovery. Sporodochia visible just above fifth joint.

Re-isolations from three of the inoculated plants yielded *F. culmorum.*

The control plants remained healthy until June 11th, 1927, when one of them showed signs of infection of the snag, evidently from the sporodochia which were being produced on the adjacent inoculated plants. The snag was removed with a sterile knife, and the control plants moved to another cucumber house, where they remained free from disease until removed some weeks after the death of the inoculated plants.

It is evident that environmental conditions determine to a great extent aerial infection and the subsequent course of the disease. In commercial carnation nurseries conditions approximating to those of the experiment of May 13th, 1927 are not found (save in exceptional cases in propagating houses), and the disease follows the course of the experiment of April 28th, 1927, proceeding relatively slowly and often fading out without causing serious damage.

C.—*Soil Inoculation.*

(a) Inoculations by watering the soil with spore suspensions of the pathogen under normal conditions have produced negative results.

(b) Eighteen plants were inoculated by introducing cultures of the pathogen on steamed carnation stems into the soil around the roots. Six plants served as controls. The plants were then potted into large pans of light soil with good drainage. After four weeks one inoculated plant wilted, and Fusarium was isolated from lesions in the stem and roots. The remaining plants remained exceptionally healthy for six months following the inoculation. The negative results obtained from this experiment suggest that uninjured roots do not become infected under conditions of good drainage and healthy root action.

(c) A tank, 6 ft. 3 in. by 1 ft. 1 in. by 1 ft. 2 in., was raised on bricks at one end. A board was placed within parallel to the ground, and the tank filled with water up to the level of the board. The space above the board was then filled with soil contaminated with the pathogen, and was planted with fourteen carnations (variety Topsy). In order to obtain thoroughly contaminated soil it was first baked, then mixed with spore suspensions, and cultures of the pathogen on rice and steamed carnation stems, and incubated in a cucumber house until pink sporodochia were visible upon the sacks in which the soil was stored, showing that the fungus had grown through the soil.

The height of the water was maintained at the level of the board, but the graduation of dry soil to wet which it had been hoped to maintain was not very marked, and the soil was usually in a partially waterlogged condition throughout.

Fresh baked soil was added from time to time, and suitable top dressings. The tank was planted on June 20th, 1927, and the surviving plants were lifted on August 28th, 1928.

The long period of this experiment—fourteen months—was considered necessary in view of the observed length of time between replanting in infected soil in commercial nurseries and the appearance of disease-symptoms (see Table III). By August 28th, 1928, six plants were dead. Re-isolations from lesions in the remaining plants showed that all but one were infected with *F. culmorum*, but the lesions were not in all cases indicative of root infection. It will thus be seen that consistent infection has not been obtained by planting in infected soil. This form of infection undoubtedly takes place in commercial nurseries, and the influence of some other factor not present in the above experiment is suspected.

CROSS INOCULATIONS.

The results of cross inoculations made on the tomato, aster and potato, are shown in Table II. It is apparent that strains of *F. culmorum* pathogenic

TABLE II.

Cross-Inoculations.

Date of Inocula-tion.	Plant.	Inoculum.	Number of Inoc-ulated Plants.	Number of Controls.	Number of Wilted Plants.	Date of Re-isola-tion.	Re-isola-tion of Fusarium.	Total Re-isola-tions.	Average Extent of Lesion.	Nature of Lesions.
26.4.27	Tomato	*F. culmorum*	6	2	0	21.5.27	0	0	1.0 cm.	pith only.
14.6.27	,,	*F. anthophilum*	6	2	0	11.7.27	5	6	v. slight	pith only.
12.5.28	,,	*F. culmorum*	12	2	0	5.6.28	10	12	1.0 cm.	pith and running in wood.
22.6.27	Aster	*F. culmorum*	6	2	4	6.10.27	2	6	6.3 cm.	pith and wood.
,,	,,	,,	6	2	0	,,	2	4	0.7 cm.	pith only.
,,	,,	*F. anthophilum*	6	2	1	,,	3	5	0.9 cm.	pith only.
12.7.27	Potato	*F. culmorum*	8	4	3	1.10.27	2	2	1.9 cm.	3 pith only. 3 complete rot.
,,	,,	,,	8	4	3	,,	4	4	6.0 cm.	8 complete rot.
,,	,,	*F. anthophilum*	8	4	0	,,	1	2	2.0 cm.	7 pith only.
,,	,,	*F. herbarum*	8	4	0	,,	7	7	2.5 cm.	6 pith only. 1 pith and wood.

to carnations can cause wilt of the aster (Plate 1, Fig. 4) and potato, and lesions in the stem of the tomato.

Pathological Anatomy.

The causal fungus is capable either of producing a pith-rot, or of travelling in the wood for considerable distances without infecting the pith. The cross plates of tissue at the nodes have the effect of checking the progress of the fungus. On splitting the stem of a diseased plant, healthy pith areas may be found alternating with browned infected pith areas, which are connected by browned wood. Fusarium has been isolated in many cases free from other organisms, from both pith and wood lesions. Where the pith only is infected, the nodal cross-plates may act as barriers for a considerable time, and examination of plants attacked by Dieback suggests that the growth of the fungus back into the main stem is often stopped in this way.

The Incidence of Disease in Commercial Nurseries.

The following observations have been made on the incidence of the disease in commercial nurseries.

(*a*) *Dieback.*

(1) The growth of the fungus from an infected snag back into the main stem is in the majority of cases stopped by the joint at the base of the snag.

(2) Where the fungus succeeds in passing the joint and working back into the stem, the extension of the lesion is so slow that many months elapse before the wilting of shoots on the stem above this point occurs.

(3) Out of many plants examined, none was found, with the possible exception of very old plants, the death of which could be attributed to Dieback. It is considered that the damage caused by the Dieback aspect of the disease is not of sufficient importance to warrant the consideration of control measures.

(*b*) *Stem Rot.*

(1) Twenty-two plants showing symptoms of stem rot were marked in November, 1925, and periodical observations made on them. Only twelve plants had shown further Wilt by the end of August, 1926, and in no case had the Wilt become complete and caused the death of the plant.

(2) Of thirteen cases of stem rot taken under observation in April, 1926, eight showed no further Wilt by August 26th. Of the remaining five, three had died by July 28th and two showed further wilted limbs.

(3) Observations in detail on a single plant with typical stem rot indicated that the time taken from infection to complete Wilt was not less than eighteen months.

(*c*) *Root Disease.*

(1) It is not unusual for beds destined later to show large infected areas to have little or no Wilt in the first year after planting. Wilt occurs most frequently at the height of the spring or summer crop, in the second year. If badly affected beds are permitted to remain, the old infected areas gradually enlarge, while new ones also appear.

(2) If bare areas are re-planted, the new plants wilt comparatively quickly, but it must be remembered that the reserve plants used for this purpose are often weakened by neglect. The progress of the disease on two infected areas that were re-planted on September 20th, 1925, is shown in Table III.

(3) It becomes of importance to ascertain if infected areas persist from one crop to the following. An attempt has been made to investigate this point. The results are shown in Fig. II., where the bed represented, which had become unprofitable owing to the large infected areas (shaded), was pulled out after three years' cropping, and re-planted. The X's mark the positions of the young plants that wilted from soil infections within four months of re-planting. The soil was disturbed by the digging in of manures prior to re-planting, so that exact correlation between the old and newly infected positions is not to be expected. The freedom of the southern third of the bed from both old infected areas and freshly wilted plants may be noted.

Sources of Infection in Commercial Nurseries.

(*a*) *Atmosphere.*

Under favourable conditions sporodochia appear on the surface of diseased plants. They occur most frequently on the stem just above soil-level, but have also been found upon roots, infected snags, on dead leaf-bases and on calyces and petals. It is not uncommon to find plants bearing sporodochia that have not yet begun to wilt.

Fresh sporodochia have been found in every month of the year, following periods of dull, damp weather, but they are most abundant during the winter months—November, December, January and February. In long damp periods in the winter, rotting buds, if infected with Fusarum, produce masses of pink sporodochia which are a prolific source of infection.

(*b*) *Water Supply Contamination.*

The water supply of a commercial nursery was filtered according to the method devised by Bewley and Buddin (2). Two Fusaria were obtained, morphologically similar to those isolated from living plants. On inoculation, one of these, *F. culmorum*, proved to be pathogenic and showed that the disease may be spread by water from a contaminated supply. Investigation of the sources

FIGURE II

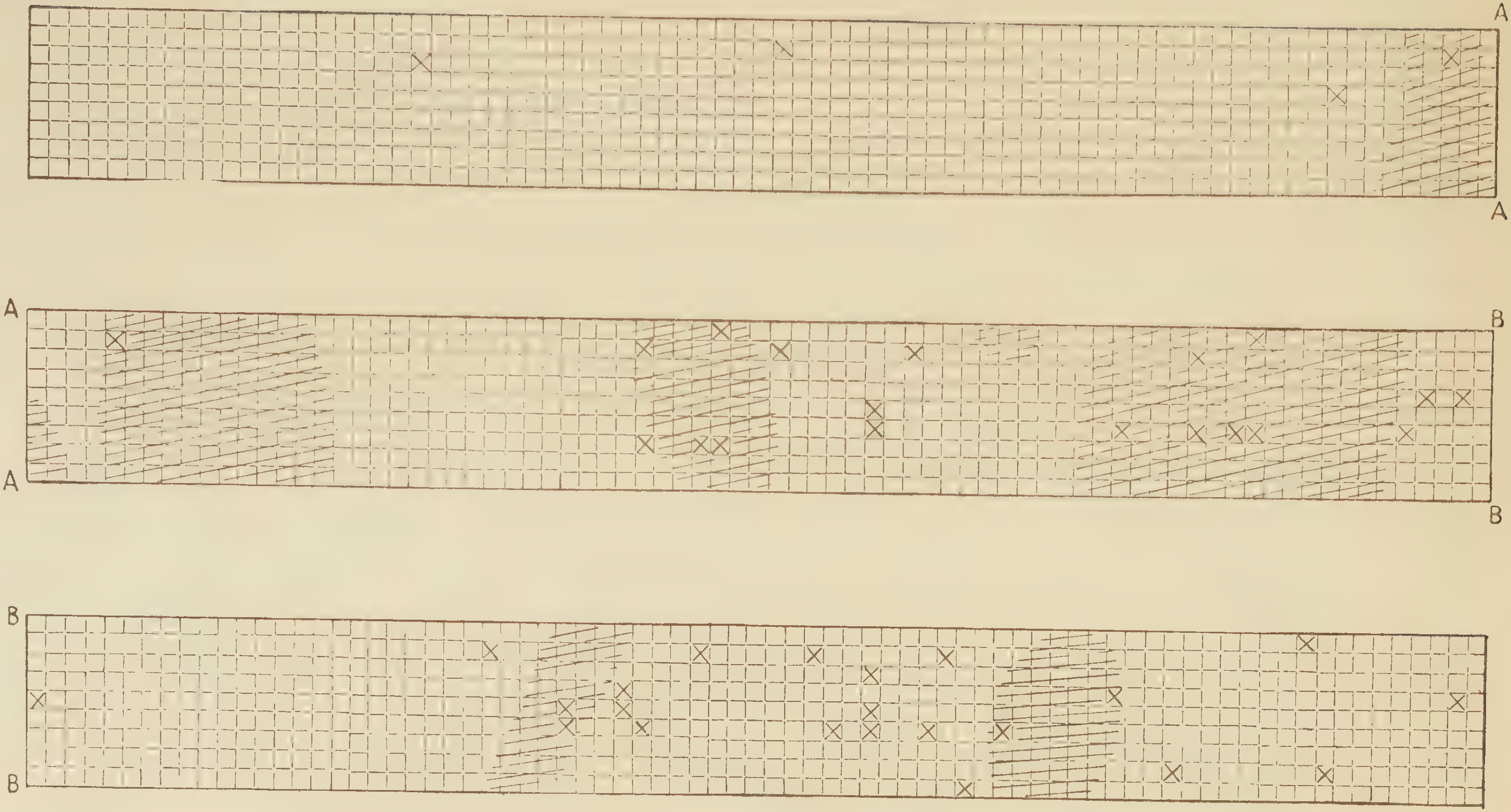


TABLE III.

Progress of Disease on Replanted Infected Areas.

Date.	Area B. "Aviator."			Date.	Area D. "Laddie."		
	Number of healthy plants.	Number of plants partially Wilted.	Number of plants Wilted.		Number of healthy plants.	Number of plants partially Wilted.	Number of plants Wilted.
20.9.25	21 (3)*	0	0	20.9.25	8	0	0
5.1.26	21 (3)	0	0	5.1.26	8	0	0
19.2.26	16 (3)	4	1	19.2.26	8	0	0
23.3.26	11 (3)	8	2	22.3.26	7	1	0
9.4.26	8 (2)	2 (1)	11	8.4.26	6	0	2
29.4.26	3 (2)	3 (1)	15	30.4.26	5	1	2
15.6.26	2 (2)	2 (1)	17	15.6.26	5	0	3
11.9.26	0 (1)	1 (1)	20 (1)	11.9.26	2	0	6

* The numbers in brackets refer to original plants left in when the area as a whole was replanted.

of the water-supplies in other nurseries points to the disease being spread in this way.

(*c*) *Contamination of the Soil.*

Species of Fusarium are known to carry on a saprophytic existence in the soil. In the present investigation Fusaria, afterwards proved to be pathogenic, have been isolated from organic matter on the surface of the paths and from decaying materials in the beds.

The commonest position for sporodochia formation is on the stem of the plant, just above soil level. Watering or spraying these sporodochia is unavoidable in the ordinary routine work of the nursery, and undoubtedly helps the dissemination of the fungus in the soil.

(*d*) *Occurrence of the fungus in virgin soil.*

The isolation of *F. culmorum*, pathogenic to carnations from asters, chrysanthemums and tomatoes (see Table I), all growing in situations that had not at any time previously contained carnations, lends strong probability to the assumption that the fungus is present in virgin soil.

MODES OF INFECTION IN COMMERCIAL NURSERIES.

The examination of many infected plants and the positions of their lesions indicates that a wound or injury almost invariably precedes infection by Fusarium. The most common points of entrance of the fungus into the plant and the ways in which injuries arise at these points in commercial nurseries are the following :

During Propagation.

(1) On the surface exposed by making a cutting. The imperfect formation of callus and the breaking away of the callus from the base of the cutting during transference from sand to compost increase the risk of infection.

(2) At soil level, both in the cutting stage and when in small pots. Especially following deep insertion of the cuttings and deep potting, or unsuitable conditions in the sand or compost.

(3) A damaged root. In potting, damaged roots easily arise by ramming rooted cuttings into infected soil. Excessive ramming increases the risk of infection by interference with the drainage.

(4) At a joint a few inches above soil level. The leaf bases collect moisture which induces decay, and aids the germination of fungal spores.

(5) At the cut surface of the snag made in stopping. Such infections are very common, but rarely pass the joint at the base of the snag.

After planting in the beds.

(6) At soil level. Bites from woodlice or wireworm, damage from accidental bending, or strain from long overdue staking, all contribute to the risk of infection. Deep planting and excessive soil moisture lead to Collar Rot, apparently by causing splitting, swelling and softening of the tissues, and the exposing of the damaged stem to soil infection.

(7) The root, following wireworm bites and other damage. Where wireworm attacks have not proved fatal infection by Fusarium has been found to follow, and a large percentage of young wilted plants, in which the source of infection may be traced to the soil, have roots or stem-bases burrowed by wireworm, gnawed by woodlice or damaged in some way by soil insects. Of forty-five plants on a newly planted bed wilted through soil infection, eighteen showed definite marks of damage from wireworm or other soil insects.

(8) At the cut surface of the snag made by the cutting of a bloom. It is impossible to avoid leaving a snag but little or no serious damage follows infection of this nature. Similar infections follow accidental breaking of shoots.

(9) The method of infection which leads to Stem Rot (See Text-Fig. 1) at the junction of the main limbs has not definitely been determined. Either the fungus gained entrance through the snag left in stopping, and the disease made such slow progress that the effects were not evident until later in the life of the plant, or, with the aid of stagnant moisture collected in the main forks of the plant. In two nurseries with contaminated water supply, plants with this type of infection were common.

(10) At a joint on a stem, high up on the plant. Probably resulting through wounds made in disbudding.

Fusarium may commonly enter a single plant at one and the same time in several different ways. Plants have been found in which the fungus was both growing up from the root and down from the top.

Effect of Environment on the Incidence of Disease.

Temperature.

(1) The period of maximum Wilt in commercial nurseries occurs during the period from April to August. The average day temperatures in degrees F. during these months in a commercial nursery were found to be :

	7 a.m.	1 p.m.	5 p.m.
April	57	68	62
May	57	71	69
June	57	73	70
July	60	75	74
August	58	75	75

The optimum temperature for the growth of nearly all Fusaria lies above 77°F. Some indication of the relative growths of carnation Fusaria at 70°F. and 77°F. is given in Table IV. With the exception of *F. sporotrichoides* and *F. culmorum* (Str. 2), all show slightly quicker growth at the higher temperatures. The growth of *F. sporotrichoides*, the bud-rot fungus, which is only weakly parasitic, was very slow at high temperatures. Indeed at 77°F its growth curve showed a falling off with time characteristic of the growth processes of plants

TABLE IV.

Time taken in Hours to reach growth diameter of 7 cm. *

	70°F.	77°F.
F. culmorum (Str. 1)	148	126
,, (Str. 2)	111	113
,, (Str. 3)	118	114
F. anthophilum	190	182
F. herbarum (Str. 1)	212	178
,, (Str. 2)	192	180
F. acuminatum	173	168
F. sporotrichoides	190	— †

* Brown's (3) synthetic medium was used to ensure uniformity throughout the series. It has the following composition :—

Glucose	2	gms.
Asparagin	2	,,
K_3PO_4	1.25	,,
$Mg\,SO_4, 7H_2O$.	0.75	,,
Agar.	15	,,
Water	1	litre.

Transfers of mycelium were made from corresponding portions of growths of the same age on Hard Potato Agar. Each reading is the mean of two duplicate plates.

† After 216 hours the average growth diameter was only 4.7 cm. at this temperature and 3.7 cm. at 80° F.

at injurious temperatures. Its preference for a lower temperature may be connected with the greater prevalence of bud-rot during the winter months, whereas Wilt, caused mainly by *F. culmorum*, reaches its maximum in the summer months.

It may be noted that the optimum temperature for the development of the carnation plant lies below 65°F.

(2) Plants inoculated by pricking *F. culmorum* into the bases of the main limbs on September 7th, 1927 were placed in positions subject to a range of temperatures.

The results are shown in Table V.

TABLE V.

Situation.	Temperature.			Number of Inoculated plants.	Number of Wilted plants.	Average number of days before Wilting.
	Max. Day.	Av. Day.	Min. Night.			
Cucumber House ..	75·5	67·73	57	12	10	19
Cool Chamber ..	72	63·5	51·5	12	8	31
Open (sheltered) ..	59	55·5	48	12	3	—

In another experiment of this nature, where the fungus was inoculated into the harder stems, no Wilt occurred; but on examination of the plants after a period of five months it was found that the lesions of the plants in a series subjected to a high temperature were considerably more extensive (average of six plants, 7.3 cm.) than the lesions of plants in a series subjected to a lower temperature (average of six plants, 3.5 cm.).

(3) Twelve plants were inoculated by placing spore suspensions of the pathogen on the cut ends of their stems. Six were placed in a cucumber house and six in a cool glass house.

Cucumber house: In two months from the date of inoculation (May 13th, 1927) the fungus had grown back almost to soil level, and the plants were killed.

Cool glass house: After six months from the date of inoculation (April 28th, 1927) Dieback had affected the two or three upper joints only. Subsequently the fungus died out without causing further damage.

Soil Moisture.

(1) During inoculation experiments made by contaminating the soil with spore suspensions, no infection has been obtained except by standing the pots in saucers and thus waterlogging the soil. The results of an experiment in which plants were grown over a long period in heavily contaminated soil are discussed on page 309.

(2) A bed in a commercial nursery planted in June, 1925, had lost only about 8 per cent. of its plants by June, 1926. By the end of August, 60 per cent. of the plants were affected by the Wilt disease, and the survivors were shortly afterwards pulled out by the grower. The plants showed typical root lesions extending up into the stem, and a virulent strain of *Fusarium culmorum* was isolated. In the preceding winter this bed had attracted the attention of the writer by reason of its damp condition and poor drainage.

(3) In a house of one-year-old plants which was practically free from Wilt, a patch involving about thirty infected plants appeared in a side bed in the spring

of 1926. This patch was found to correspond with a place on the path outside which was above the level of the bed inside, where the water had collected during heavy rainfall in the preceding winter. In a similar case in another nursery the only infected area on a side bed was found to be also the area of flooding caused by a defect in the drainage system.

Atmospheric Humidity.

Conditions of high atmospheric humidity have always been observed, in commercial nurseries and under experimental conditions to produce growth of aerial mycelium and abundant sporodochia, thus increasing the sources of infection.

It is evident that favourable environmental conditions accelerate the course of the disease, and that whereas its progress in commercial nurseries, under normal conditions, is very slow, outbreaks in epidemic form may in some cases be attributed to favourable environmental conditions such as high temperature and excessive soil moisture.

Varietal and Constitutional Susceptibility.

None of the varieties commonly used for commercial purposes has been found to be either immune or resistant. With the doubtful exception of Aviator, no variety has proved consistently susceptible. The variation in susceptibility exhibited by the same variety in different nurseries is sufficiently marked to require consideration.

In past years, cases of outbreaks of Wilt disease have been reported on the continent (1), following the importation of stock from other nurseries. The cause of such an outbreak might be either the constitutional susceptibility of the stock or the introduction of it to a virulent strain of the fungus. There is a certain amount of evidence suggesting that such an outbreak has recently occurred in this country.

The variation in constitutional resistance of stocks propagated in different nurseries may well be an explanation of the fact that the same variety contracts the disease badly in one nursery and remains practically free in another where, perhaps, the general infection is more severe.

Control Measures.

Elimination of sources of infection.

(1) The possibility of the introduction of this disease should be the first concern of the nurseryman in buying stock from outside sources.

(2) Contamination of the water supply has been proved to exist and may be considered likely in all cases where there are large open reservoirs, or where the water supplies receive additions from surface drainage.

(3) Wilting plants should be *dug* up intact, not pulled out by hand. The advanced nature of the lesions which, in the root-system, have usually been followed by secondary bacterial infections and soft rot before symptoms of Wilt are shown by the top, make it extremely difficult to lift the plant without leaving sources of infection in the soil.

Avoidance of conditions Favourable to the Disease.

(1) A sharp knife should be used for making cuttings, since it has been noted that infection of imperfectly calloused surfaces is common. Insertion of cuttings in sand or compost to a depth greater than a quarter of an inch is unnecessary for purposes of rooting, and increases the risk of Collar Rot. Rooted cuttings should be potted carefully, to avoid injuries to the young roots.

(2) When planting in beds, shallow rather than deep planting is preferable. The carnation does not produce adventitious roots readily, and isolated cases of Collar Rot have frequently been associated with over-deep planting.

(3) Considerable variation exists in the rate of growth and in the water requirements of different varieties. If, when watering, differential treatment is neglected, conditions of excessive soil moisture favourable to the disease easily arise. The variety Topsy suffers most in this way.

Rotation of Crops.

Rotation of crops has been suggested by a previous writer (11) as a control measure for the Wilt disease. In this country the most suitable glasshouse crop for this purpose would be tomatoes; but the isolation of *Fusarium culmorum*, pathogenic to carnations, from the roots of Tomato plants grown in houses at the Cheshunt Experimental Station in which no carnations have ever been grown suggests that this rotation could hardly be recommended.

Soil Sterilisation.

The outbreak of the disease in large areas which remain infected for a considerable time makes some form of soil sterilisation a necessity. The effects of chemical sterilisation agents on Wilt diseases caused by the other Fusaria, and comparable to that under discussion in the present paper, are far from encouraging. Steam sterilisation, on the other hand, is objected to by many growers on the ground that soil so treated is not suitable for commercial flower-production. Prejudice appears to be the only foundation for their objection, and the few growers who have adopted this method of control, far from condemning it, are enthusiastic, and state that increased crops have resulted from its use. It is considered that in the absence of an immune variety, the development and extension of soil sterilisation in commercial carnation nurseries is essential for the proper control of Wilt disease

Development of Resistant Strains.

The most satisfactory solution of the Wilt problem is offered by the possibility of the development of strains of the plant immune from or highly resistant to the disease. Control of similar Wilt diseases of Cowpea (6), Cotton (7), Tomato (9), etc., has been obtained in America in this way. There is no reason to doubt that resistant strains of the carnation could also be obtained.*

Preservation of the Quality of Carnation Stocks.

The widespread sources of infection—spores carried through the atmosphere, contamination of the water supply, soil contamination or young infected stock brought on to the nursery—indicate the importance of preserving the quality and inherent resistance to disease of carnation stocks. Few of the varieties in demand for their commercial qualities last many years; the weakening of the strains renders them unprofitable, and other commercial varieties arise to take their place. Moreover, the practice of continuous vegetative propagation by cuttings eliminates the re-combination of genetical characters through sexual propagation which to some extent perhaps, may be regarded as a safeguard against degeneration. The development of modern intensive methods of culture in order to keep pace with the growing demands of the carnation industry has, in all probability, lowered the disease resisting powers of carnation stocks, and has been one of the main causes of the spread and increase in intensity of the Wilt disease in recent years.

In conclusion, it is a pleasure to record that the writer is much indebted to Dr. W. F. Bewley, who suggested that this work should be undertaken, for his kindly encouragement and criticism. He is also indebted to Mr. W. Corbett, of the Cheshunt Experimental Station, for the photographs in Plate I.

SUMMARY.

(1) The Wilt disease of the carnation in this country is caused mainly by species of Fusaria. These include *F. culmorum*, *F. acuminatum*, *F. anthophilum* and *F. herbarum*. Different forms of the disease, differing in severity, follow different types of infection. There is no correlation between the type of infection and the different species causing the disease.

(2) In addition to Fusaria isolated from the carnation, strains of *F. culmorum* from the aster, chrysanthemum and tomato, growing in situations which had not been occupied at any time previously by carnations, are pathogenic to the carnation.

(3) *F. culmorum*, pathogenic to the carnation, causes Wilt of the potato and aster, and lesions in the stem of the tomato.

* In Table III. it may be seen that three of the original plants shower greater disease-resistance. Indeed one outlived all the replants. This plant as, in other cases, was a "rogue" of vegetative habit, and commercially useless. Observations suggest this type of plant to be definitely resistant to the Wilt Disease.

(4) *F. sporotrichoides*, associated with carnation bud-rot, can also cause Wilt. It differs from other carnation Fusaria in its slower growth at higher temperature.

(5) The progress of the disease in commercial nurseries is most rapid in the root disease type of infection, where the soil becomes infected over relatively large areas. It is relatively slow in cases of aerial infection of cut stems, where the damage caused is of little commercial importance.

(6) The sources of infection in commercial nurseries are dispersal of spores by air currents, contaminated water supply and contamination of the soil. There is strong probability that the pathogen exists in virgin soil.

(7) Infection occurs, in nearly all cases, through a wound or an injury. An account is given of the main positions of infection and of the ways in which injuries arise at these points in commercial nurseries.

(8) The period of maximum Wilt occurs during the months of high temperature, from April to August. Excessive soil moisture and atmospheric humidity favour the disease.

(9) The negative results obtained from soil inoculations on plants grown under conditions making for healthy root action, and the effect of high temperature and excessive soil moisture on the progress of the disease suggest that spread of the disease in epidemic form may in some cases be attributed to environmental conditions.

(10) Variation in constitutional resistance of the same variety, propagated in different nurseries, is suggested as an explanation of the fact that varietal susceptibility differs markedly in different nurseries.

(11) The elimination of outside channels of infection, such as the importation of infected stock or a contaminated water supply, the avoidance of environmental conditions favourable to the disease and of injuries to the plant that increase the risk of infection, soil sterilisation of badly infected beds by steam, and selection of a healthy stock for propagation, are recommended as the principal measures of control. Rotation of crops, as practised by the alternation of carnations and tomatoes is considered of little promise. The possibility of the development of a strain resistant to or immune from the disease offers the best solution of the Wilt problem.

Explanation of Figure II.

Each small square marks the position of a plant in the bed, which is, for convenience, represented in three sections. The shaded portions represent the infected areas of a previous crop. The X's mark the positions of plants wilting from soil infection within four months of replanting the bed.

Explanation of Plate 1.

Fig. 1. Showing damage caused by the disease in a commercial nursery. *Fusarium acuminatum* was isolated from the plants in the foreground.

Fig. 2. Showing the growth of *F. culmorum* on the cut stem of a young plant, " stopped " in the usual commercial manner, four days after inoculation in a moist chamber with a spore suspension.

Fig. 3. Showing, on the right, Wilt of the plant as a whole, from soil inoculation. On the left a control plant.

Fig. 4. Showing, on the right, Wilt of aster, twenty-six days after inoculation with *F. culmorum*. At the time of inoculation the plant was similar in size and appearance to the control plant (on left).

References.

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BOOK REVIEWS.

THE SCIENTIFIC PRINCIPLES OF PLANT PROTECTION.

By HUBERT MARTIN, M.Sc., A.R.C.Sc., A.I.C. Edward Arnold and Co. 21s.

DURING the last twenty years our knowledge of the control of plant diseases occurring in this country has increased considerably. Not only have many specific diseases and their causes been investigated, but the general principles which underlie the methods employed in protecting plants against infectious diseases and predatory pests have also received much attention. The fact remains, however, that the materials generally employed for controlling some of the commonest diseases of cultivated plants are still far from ideal. It is significant that the Imperial Agricultural Research Conference, held in 1927, called attention to " the paucity of materials in use in insecticides and fungicides," and recommended therefore " that an investigation of the whole chemical field should be undertaken by chemists working in collaboration with entomologists and plant pathologists."

The publication of the book under review is therefore most opportune. Its scope is aptly described in the title, for the author endeavours, with great success, to show how the empirical methods of the past are being superseded by more modern ones based on " scientific principles." Chapters on " Plant Protection " and " The Influence of External Factors on the Susceptibility and Liability of the Plant to Attack " are followed by five chapters on fungicides and insecticides. The chapter on " Toxic Action and Chemical Constitution " is one of the most important of the book, for real progress in the preparation of new spray materials is likely to result from careful systematic investigation. Information is given concerning Weedkillers, Fumigants, Seed Treatment, Soil Treatment, Biological Control, Traps, and the Treatment of the Centres and Vectors of Infection. The book thus enables all who are interested in agricultural science to obtain a comprehensive view of the methods which have evolved in the attempt to produce healthy crops, and it paves the way for the specialist research worker in this field of work.

It is to be regretted that the book is not free of errors, for although they hardly detract from its great value as a fund of information, they tend to leave an unfavourable impression. Some of these are mere printers' errors, but others include mistakes in scientific names and in the names of two authors quoted. The Gall Mites for instance are referred to the family *Phytopidae* (p. 149) and it is stated that the Black Currant Mite is the only important pest of the group, whereas the Gall Mites properly belong to the family *Eriophyidae*, and several other species, such as the Pear Leaf Blister Mite, the Citrus Rust Mite and the Woolly Mite of cotton are of economic importance also.

The numerous and up-to-date references to original papers (some 700 authors are quoted) form an important feature. We feel diffident, therefore, to ask for more, especially as the work of British investigators has generally received its due, but we should like to see some reference to Pethybridge's work

on the preparation of Burgundy Mixture in relation to the control of Potato Blight in Ireland, and to the apple spraying trials of Grubb, particularly with regard to his advocacy of the use of "excess lime" Bordeaux Mixture to reduce "Bordeaux Injury." In the chapter entitled "Traps" no mention is made of the classic example of successfully controlling Flea Beetles by various mechanical devices. The trapping of numerous insects by jarring the infested plants and catching the insects on tarred boards underneath was worthy of mention.

Although there is a passing reference to Wart Disease of potatoes on page 21, it is not mentioned at all under the heading "The Use of Resistant Varieties" (pages 12-14). This disease is perhaps the best example of the value of breeding varieties resistant to, or immune from, a specific disease. The comparative freedom of Northern Spy apple stock from attacks of Woolly Aphis is referred to very briefly on page 27 (where the variety is mentioned as "Northern Sky"), and no reference is made to the pioneer work of Staniland and of Le Pelley on the resistance of apple stocks to attacks of the Woolly Aphis.

The field covered by the book is so wide, however, that probably every reviewer could find suggestions for further inclusions. On the whole Mr. Martin has selected his material very judiciously, and the result is a most interesting exposition of the manner in which science is being applied to the solution of some of the many problems confronting those engaged in agricultural and horticultural practice.

H.W.
A.M.M.

NINTH INTERNATIONAL HORTICULTURAL CONGRESS, LONDON, 1930.

PRELIMINARY NOTICE.

At the Eighth International Horticultural Congress, held at Vienna, Austria, in 1927, an invitation from the Royal Horticultural Society to hold the next International Horticultural Congress in London was accepted. It has been decided that the Ninth International Horticultural Congress shall be held in London from August 7th to August 15th, 1930, immediately before the Fifth International Botanical Congress, which is being held in Cambridge from August 16th to August 23rd.

An Executive Committee has been appointed by the Society to make the necessary arrangements for the Congress. The members of this Executive Committee are Professor B. T. P. Barker, M.A., of the University of Bristol; Mr. E. A. Bowles, M.A., V.M.H., F.L.S., F.E.S.; Mr. E. A. Bunyard, F.L.S.; Mr. F. J. Chittenden, F.L.S., V.M.H., Director of the R.H.S. Gardens at Wisley; Sir Daniel Hall, K.C.B., M.A., F.R.S., Director of the John Innes' Horticultural Institute; Mr. R. G. Hatton, M.A., of the East Malling Research Station; Sir William Lawrence, Bt.; Mr. G. W. Leak; Mr. C. T. Musgrave, V.M.H., Vice-Chairman of the Royal Horticultural Society; Dr. A. B. Rendle, M.A., F.R.S., V.-P.L.S., V.M.H., of South Kensington Museum, and Mr. H. V. Taylor, O.B.E., B.Sc., Horticulture Commissioner to the Ministry of Agriculture and Fisheries; the Secretary of the Royal Horticultural Society acting as Secretary.

The subscription for membership of the Congress will be £1 (one pound sterling), which should be paid to the Secretary of the Royal Horticultural Society, Vincent Square, S.W.1.

PRELIMINARY PROGRAMME FOR THE CONGRESS:

August 7th	Assemblage of Congress.
August 8th	Opening of Congress.
	Lectures in the afternoon.
August 9th and 10th ..	Excursions both days.
August 11th and 12th ..	Lectures both days.
August 13th	Excursions all day.
August 14th	Lectures in the morning. Flower Show.
August 15th	Final Report of Congress by Chairman.
	Flower Show.
	Close of Congress.

The main subject for discussion at the Congress will be "Propagation, vegetative and seminal," for which papers and communications have been and are invited, and Dr. Van der Lek (Holland), Dr. R. J. Graham (Great Britain), Professor Priestley (Great Britain), Niels Esbjerg (Denmark), G. E. Yerkes (U.S.A.), Carl A. Dahl (Sweden), Dr. Webber (U.S.A.), Professor Faes (Switzerland), Franz Richter (France), Professor Denny (U.S.A.), Miss M. E. Reid (U.S.A.), Dr. Redcliffe Salaman (Great Britain), and Dr. Erwin Baur (Germany), etc., etc., have signified their intention of presenting papers.

Papers in other sections have been arranged and the Committee invites suggestions for consideration.

An extensive programme for visits to research stations and gardens of horticultural interest throughout the Kingdom is being arranged.

The Committees appointed at the Congress held in Vienna in 1927 will present their reports:—

Committee I.—On Nomenclature.

Committee II.—On Awards.

Committee III.—On Colour.

Committee IV.—On Horticultural Institutions and Research.

Committee V.—On International Exchange of Young Gardeners.

Committee VI.—On the Development of the International Committee.

Communications made to the Congress by means of papers, or participation in the general discussion, will be permissible in English, French and German. Further information will be sent in due course to all who signify their intention to attend the Congress, or will be issued to the Press from time to time.

The Secretary is anxious to receive early notification from those intending to be present at the Congress.

All correspondence should be addressed to the Secretary of the Royal Horticultural Society, London, S.W.1.